US010250094B2

(12) United States Patent
Wang et al.

(10) Patent No.: US 10,250,094 B2
(45) Date of Patent: Apr. 2, 2019

(54) **WOUND STATOR OF AN ALTERNATOR AND VEHICLE ALTERNATOR**

(71) Applicant: **Victory Industrial Corporation**, New Taipei (TW)

(72) Inventors: **Chun-Yuan Wang**, New Taipei (TW); **Ming-Laang Liou**, New Taipei (TW)

(73) Assignee: **Victory Industrial Corporation**, New Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 300 days.

(21) Appl. No.: **15/160,265**

(22) Filed: **May 20, 2016**

(65) **Prior Publication Data**

US 2016/0268861 A1 Sep. 15, 2016

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/467,057, filed on Aug. 25, 2014, now Pat. No. 9,831,732, and (Continued)

(30) **Foreign Application Priority Data**

Jul. 1, 2014 (TW) .... 103122764 A
Jul. 1, 2014 (TW) .... 103122779 A
(Continued)

(51) **Int. Cl.**
H02K 3/04 (2006.01)
H02K 3/28 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H02K 3/28*** (2013.01); ***H02K 1/226*** (2013.01); ***H02K 1/243*** (2013.01); ***H02K 3/12*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H02K 15/0478; H02K 15/0471; H02K 15/0492; H02K 3/12
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,501,205 B1 * 12/2002 Asao H02K 3/12 310/184
7,281,312 B2 * 10/2007 Sadiku H02K 15/066 29/596
(Continued)

FOREIGN PATENT DOCUMENTS

CN 101371423 A 2/2009
CN 204391912 U 6/2015
(Continued)

OTHER PUBLICATIONS

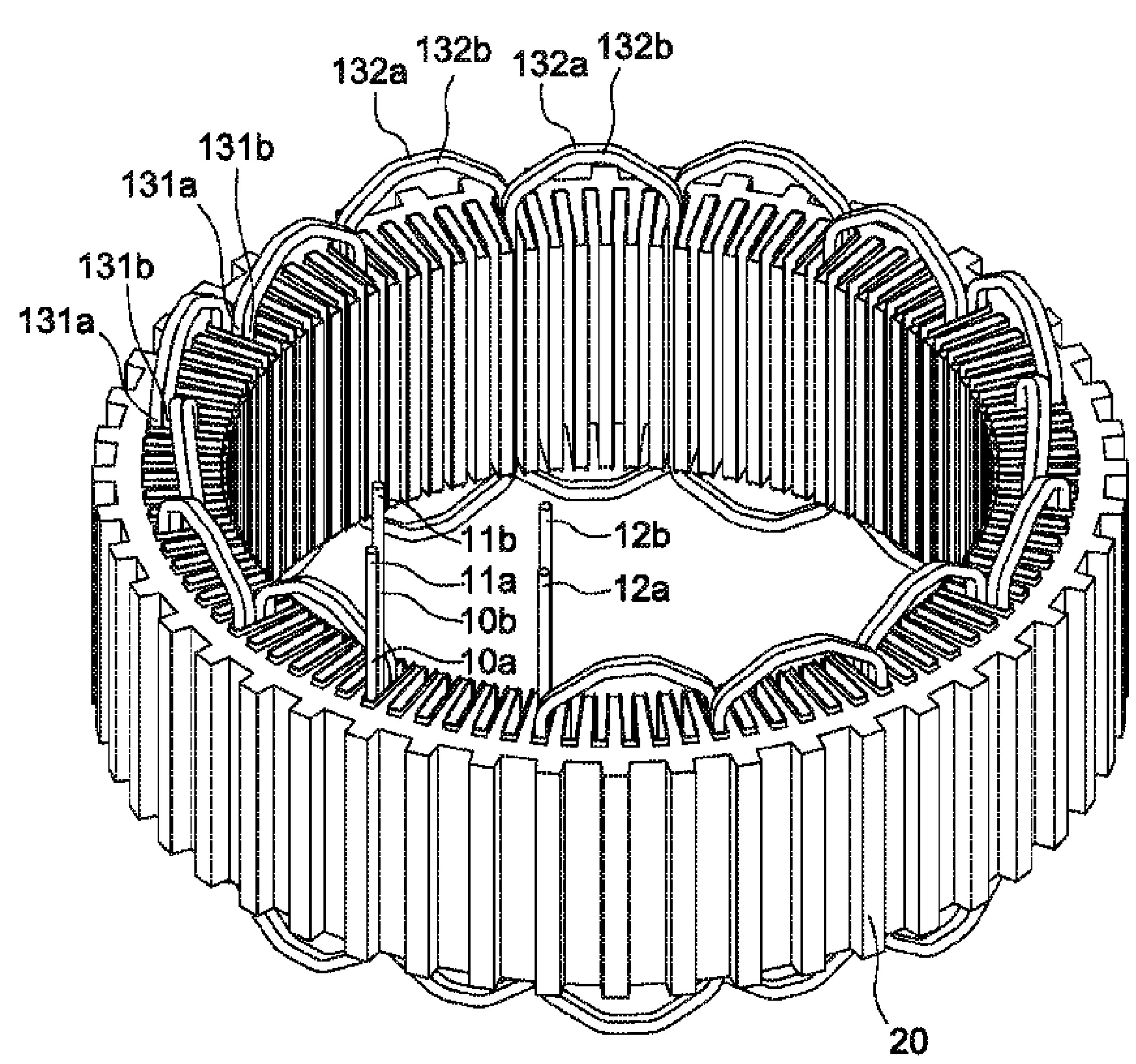
TW examination report for related TW application 104 139 765.

Primary Examiner — Hanh N Nguyen
(74) *Attorney, Agent, or Firm* — Clifford Perry

(57) **ABSTRACT**

The present invention relates to a wound stator of an alternator, which comprises: a stator and a group of wires wound thereon. The group of wires comprises a plurality of abreast wires sequentially embedded in corresponding grooves of the stator, and the abreast wires in the grooves are oriented in a radial direction of the stator.

8 Claims, 12 Drawing Sheets



Related U.S. Application Data

a continuation-in-part of application No. 14/467,058, filed on Aug. 25, 2014, and a continuation-in-part of application No. 14/467,060, filed on Aug. 25, 2014, now Pat. No. 9,831,730, and a continuation-in-part of application No. 14/467,062, filed on Aug. 25, 2014, now abandoned.

(30) **Foreign Application Priority Data**

Jul. 1, 2014	(TW)	103122780 A
Jul. 1, 2014	(TW)	103122782 A
Nov. 27, 2015	(TW)	104139765 A

(51) **Int. Cl.**

H02K 1/24	(2006.01)
H02K 1/22	(2006.01)
H02K 3/12	(2006.01)
H02K 21/04	(2006.01)
H02K 15/04	(2006.01)
H02K 3/34	(2006.01)

(52) **U.S. Cl.**
CPC ***H02K 15/0478*** (2013.01); ***H02K 21/044*** (2013.01); *H02K 3/345* (2013.01)

(58) **Field of Classification Search**
USPC 310/201, 207, 208
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,297,101 B2 *	10/2012	Bowman	B21F 1/00	72/379.6
2003/0011268 A1	1/2003	Even et al.		
2004/0261255 A1 *	12/2004	Stroebel	H02K 3/28	29/606
2009/0121576 A1 *	5/2009	Even	H02K 3/12	310/208
2009/0260217 A1 *	10/2009	Kamakura	H02K 3/12	29/596
2015/0214794 A1	7/2015	Chang et al.		
2016/0006308 A1	1/2016	Wang et al.		

FOREIGN PATENT DOCUMENTS

FR	2968858 B1	7/2013
TW	M 495672 U	2/2015
TW	201530980 A	8/2015

* cited by examiner

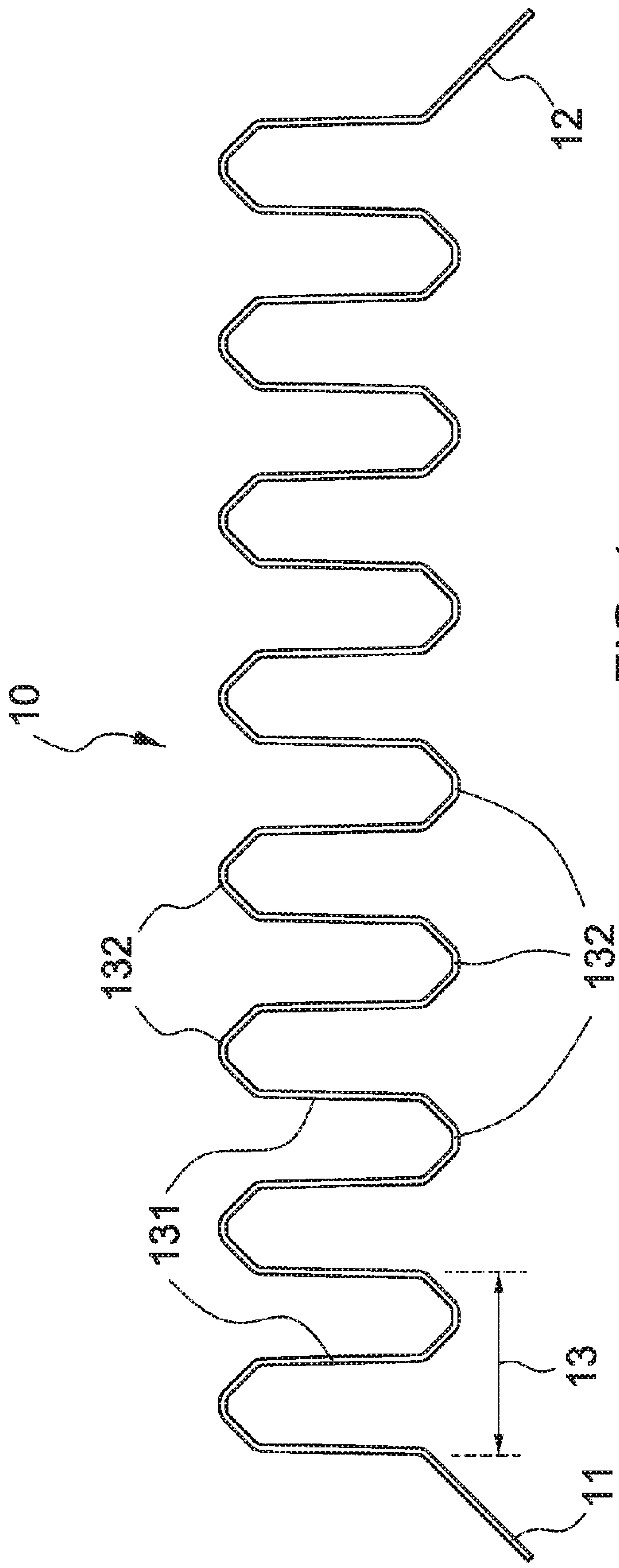


FIG. 1

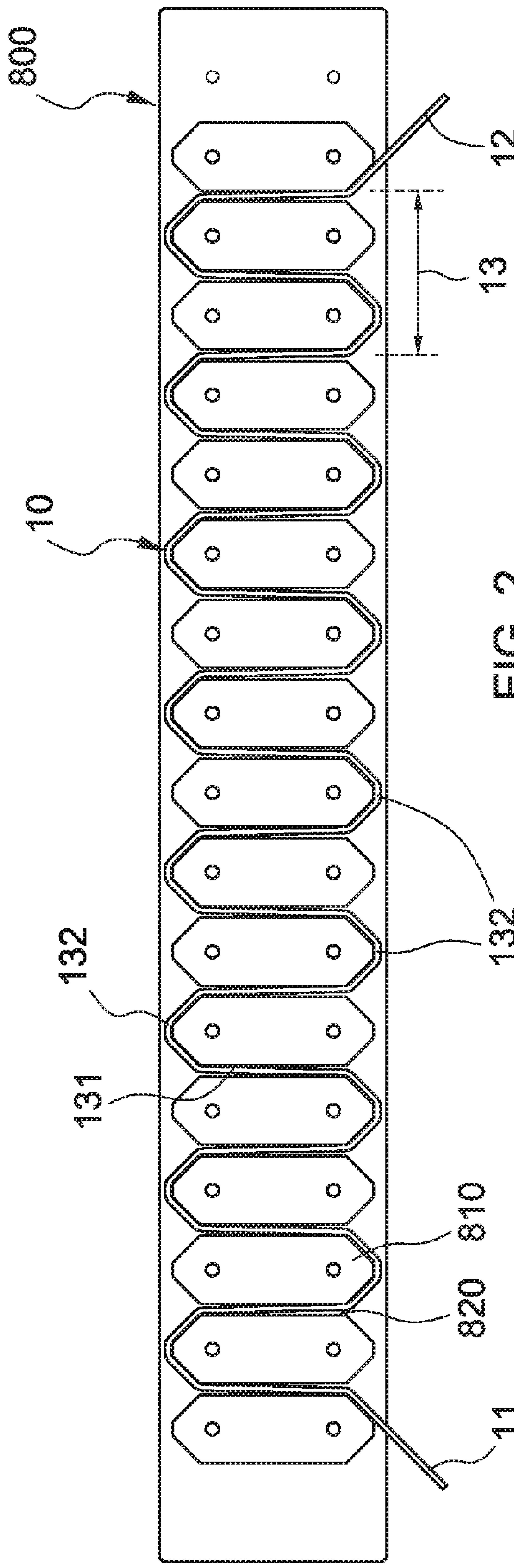


FIG. 2

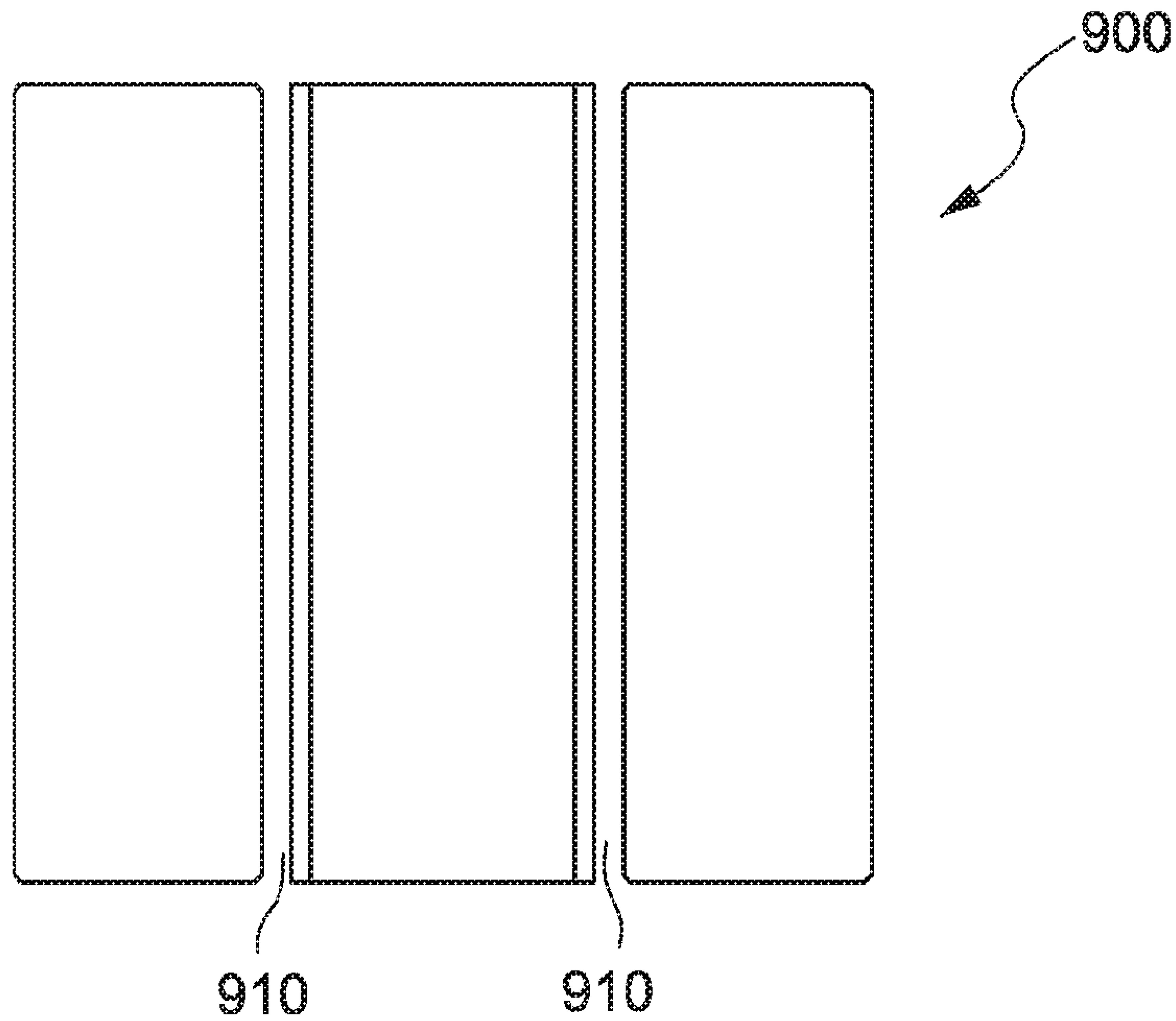


FIG. 3A

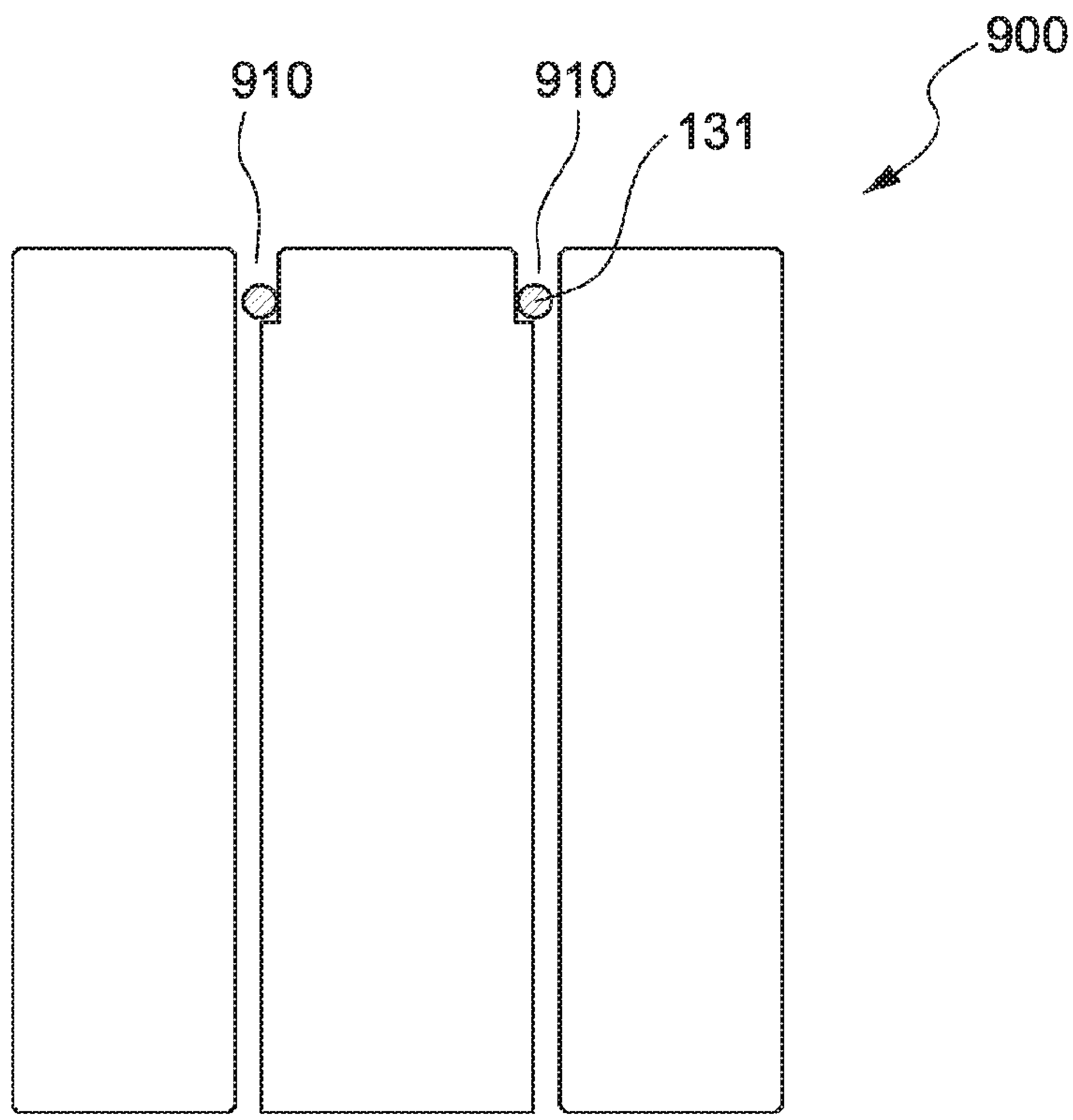


FIG. 3B

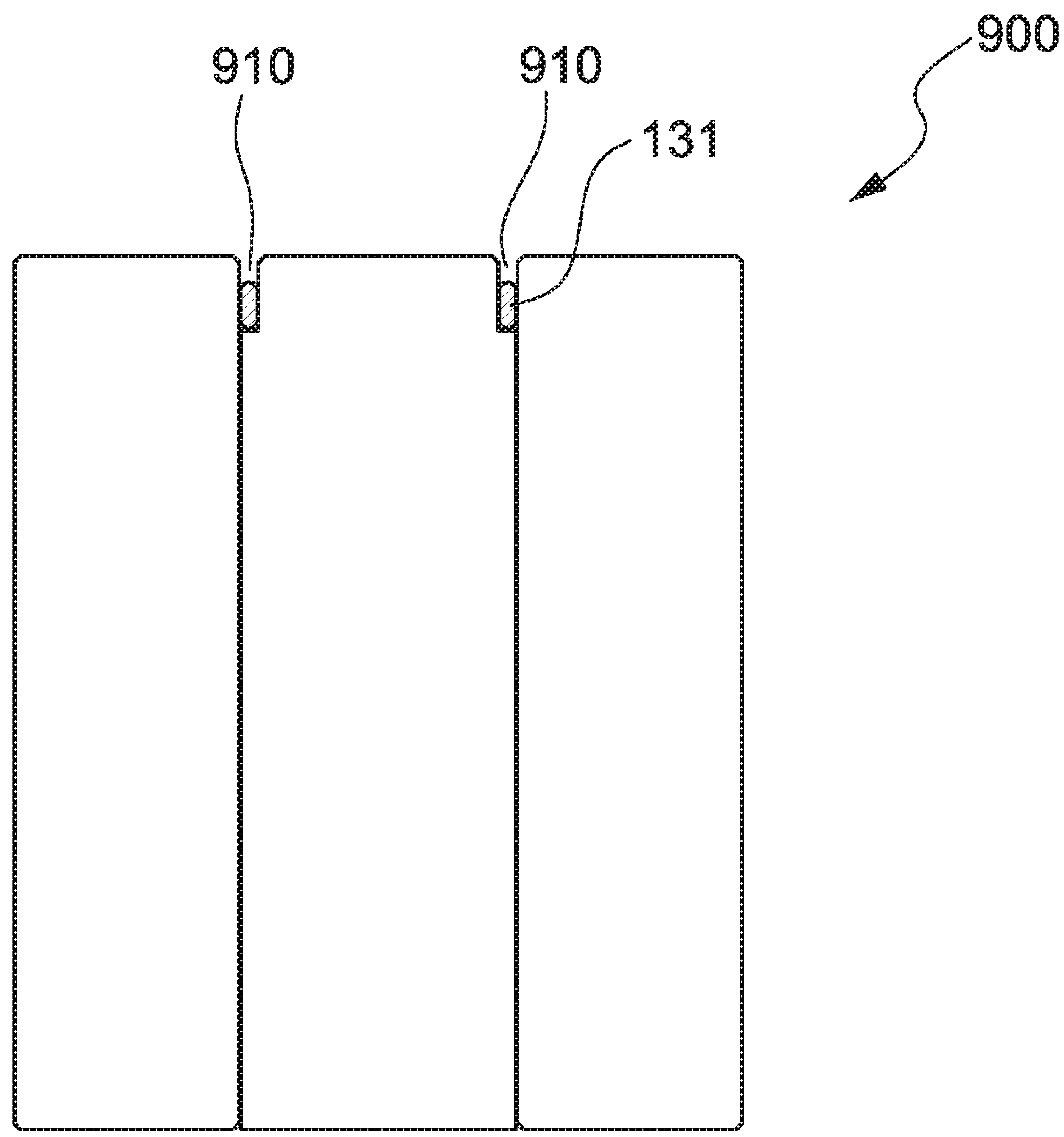


FIG. 3C

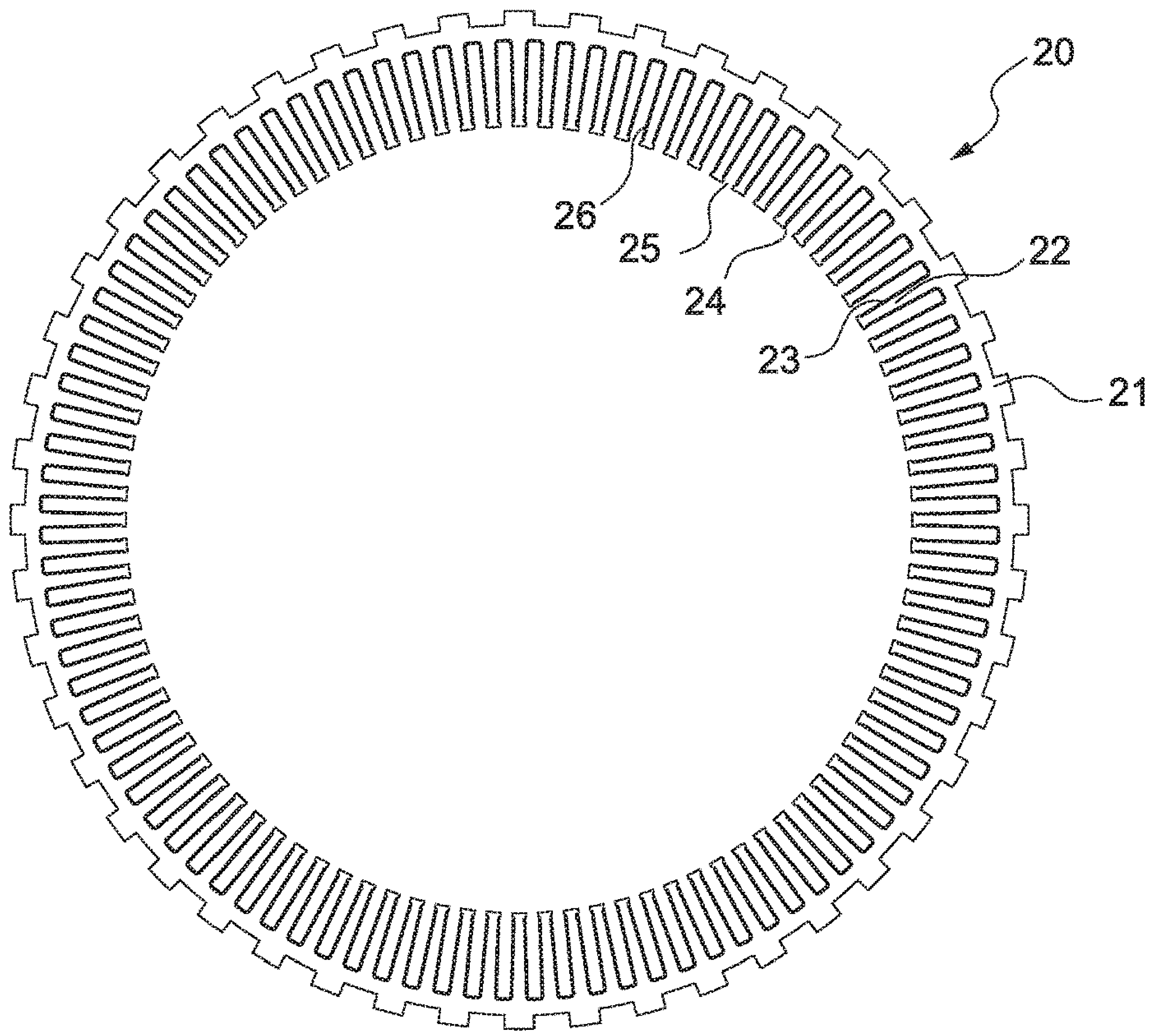


FIG. 4A

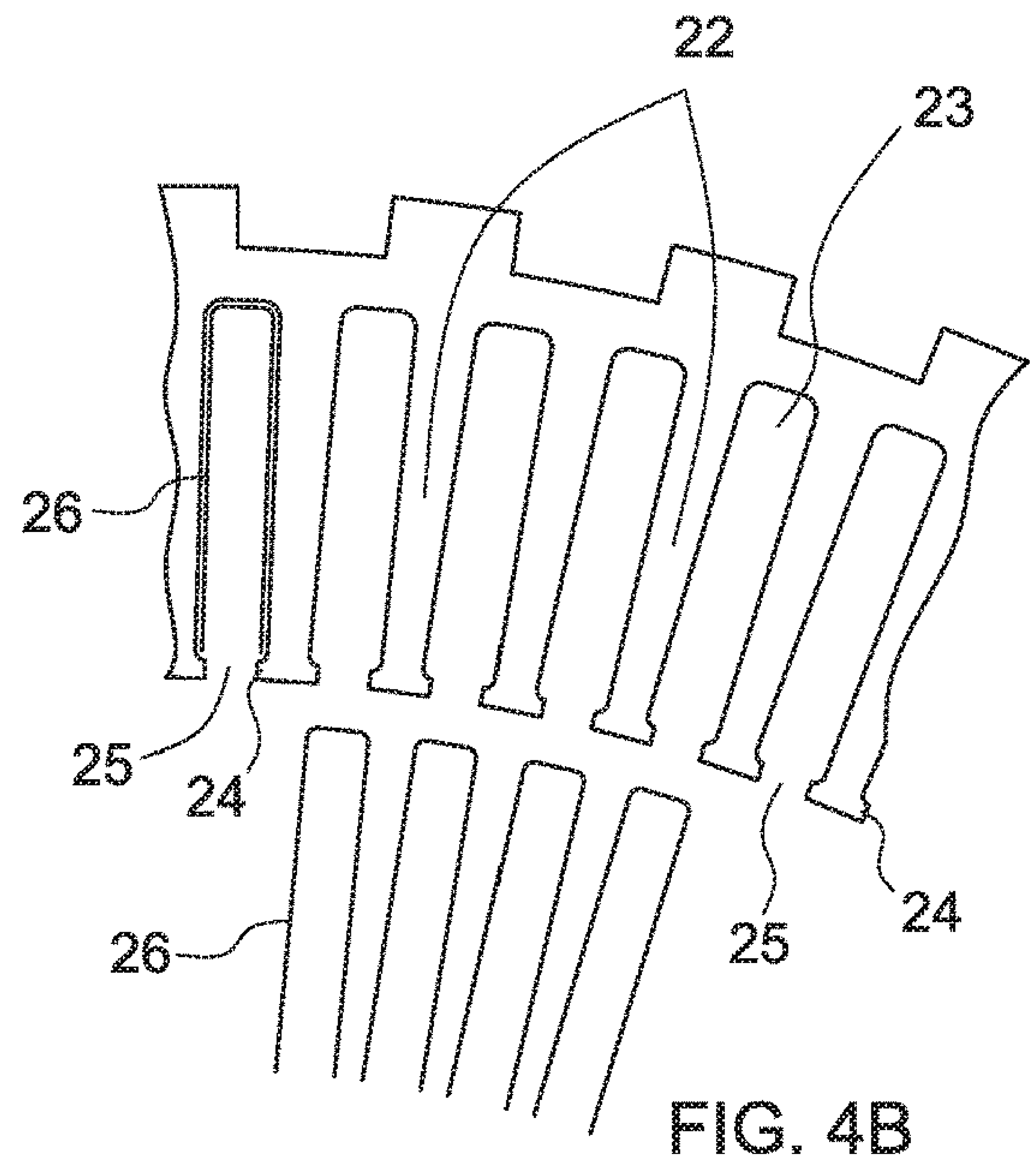


FIG. 4B

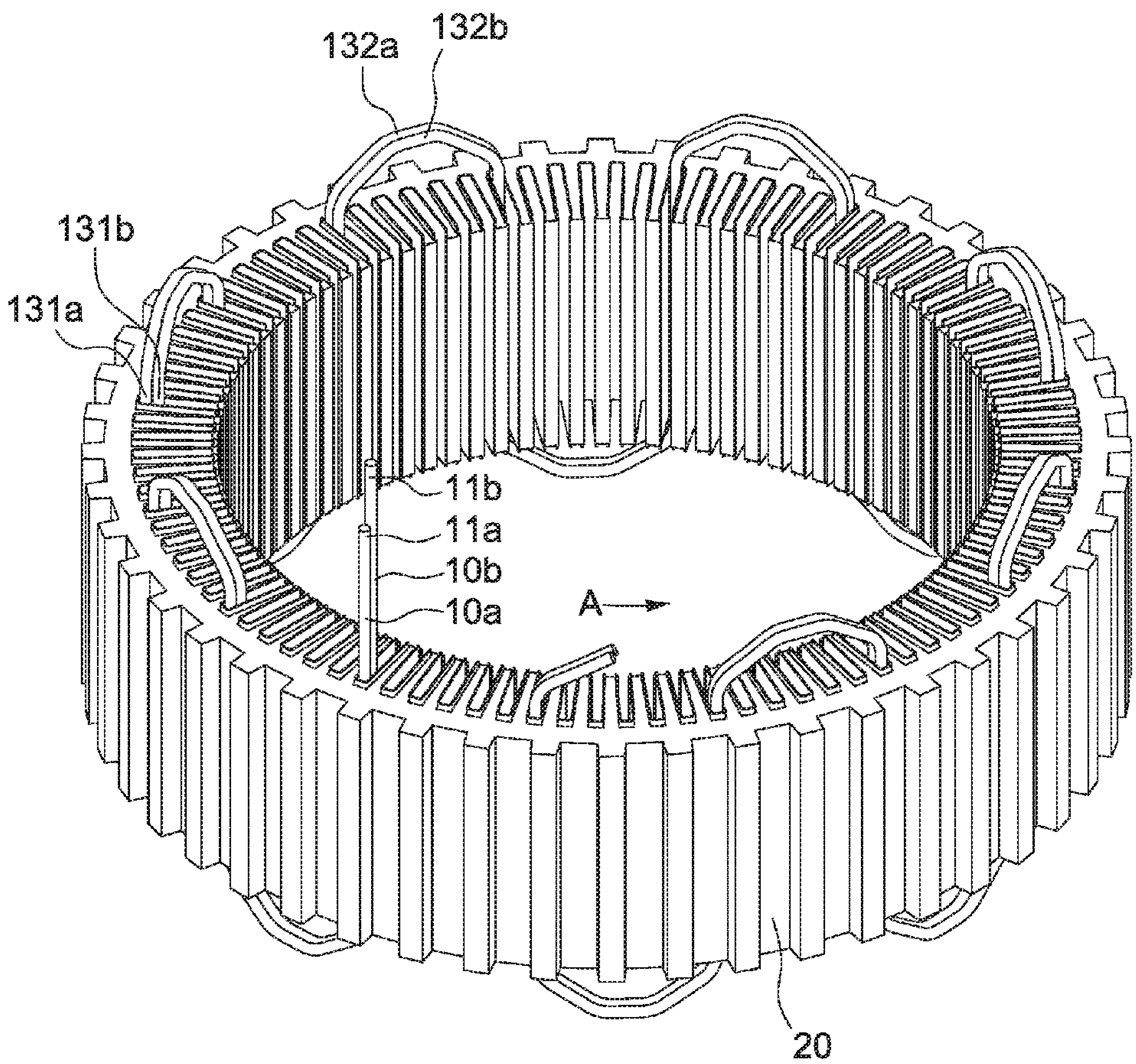


FIG. 5A

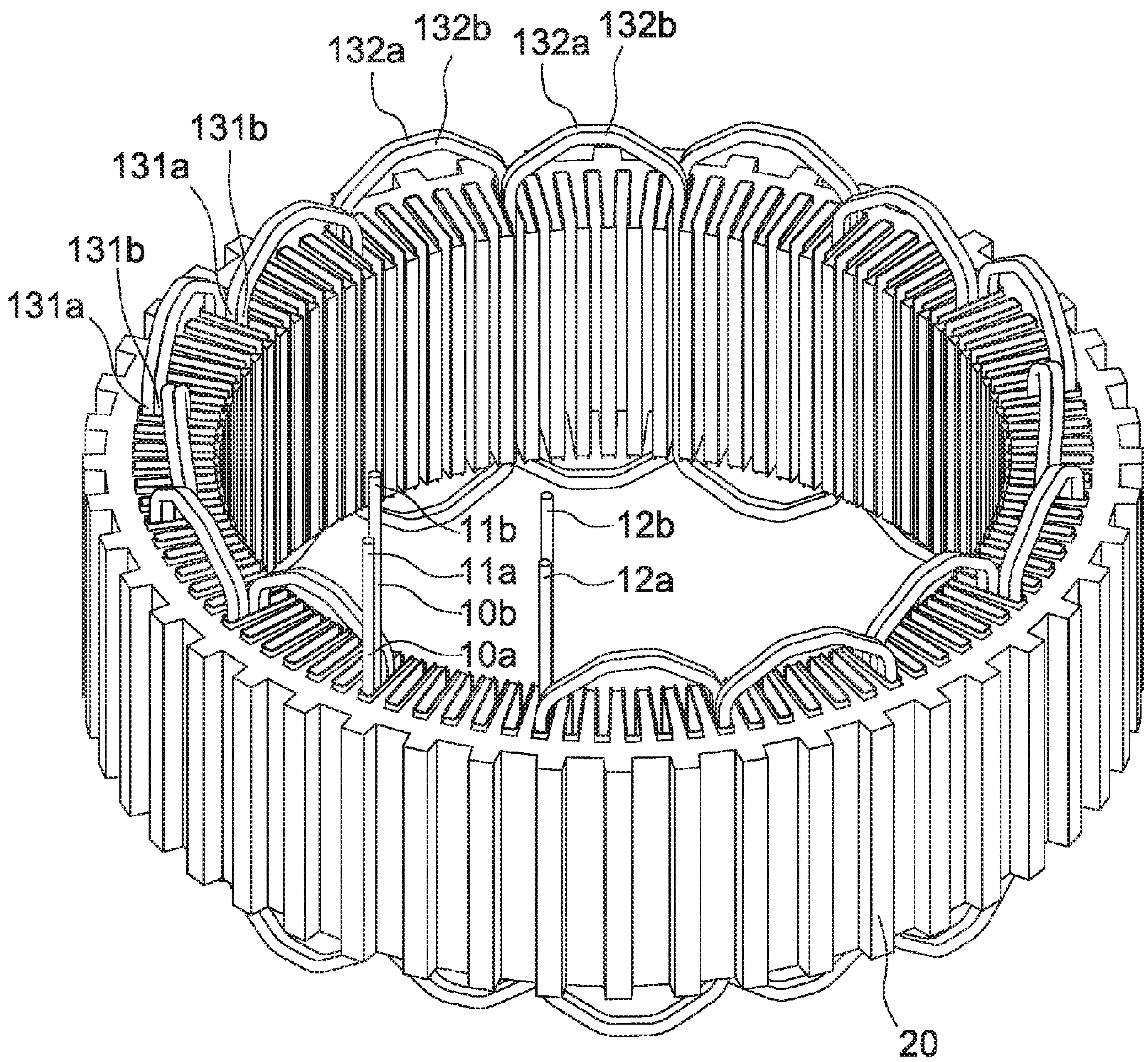

132a
132b
132a
132b
131b
131a
131b
131a
11b
12b
11a
12a
10b
10a
20

FIG. 5B

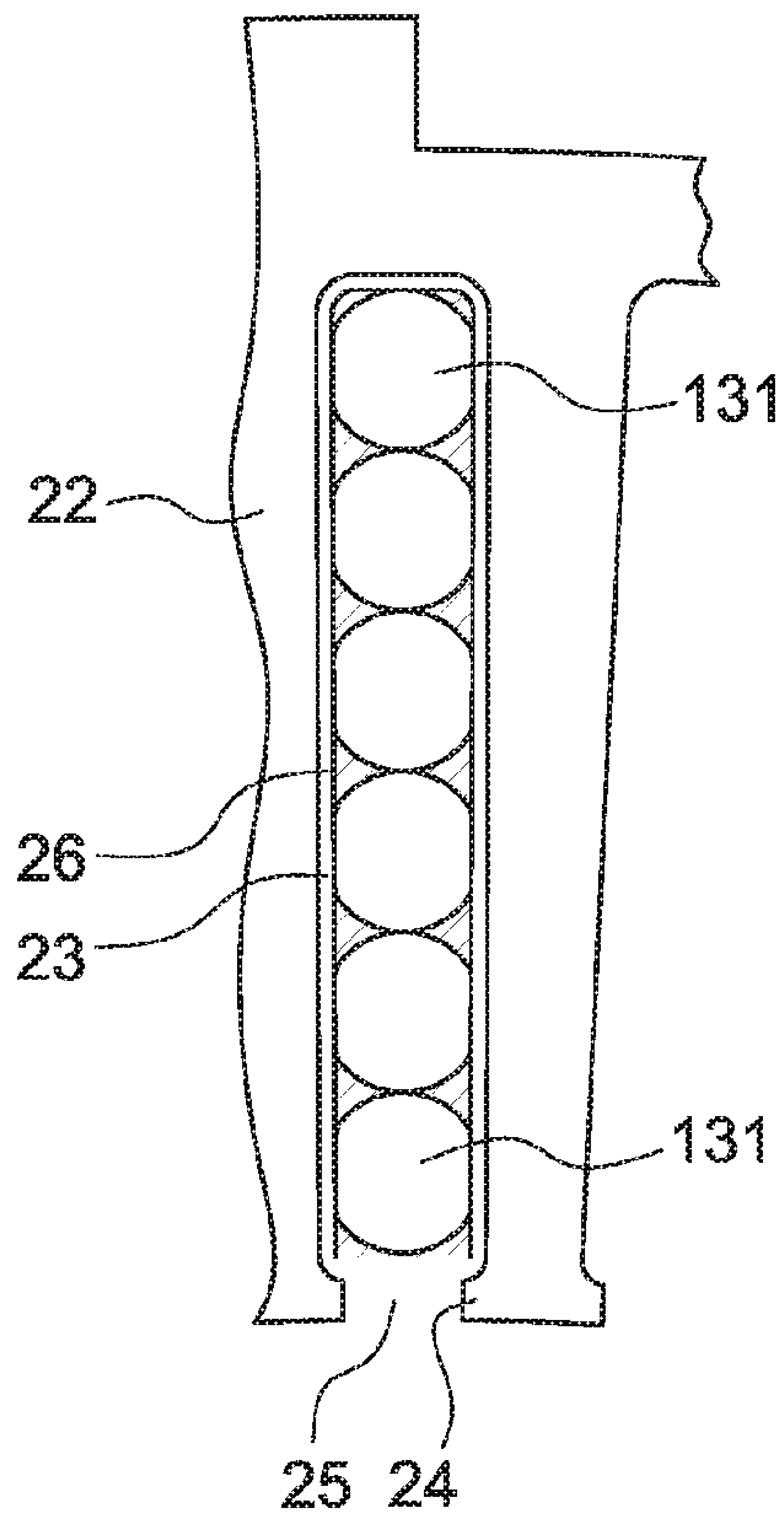


FIG. 6

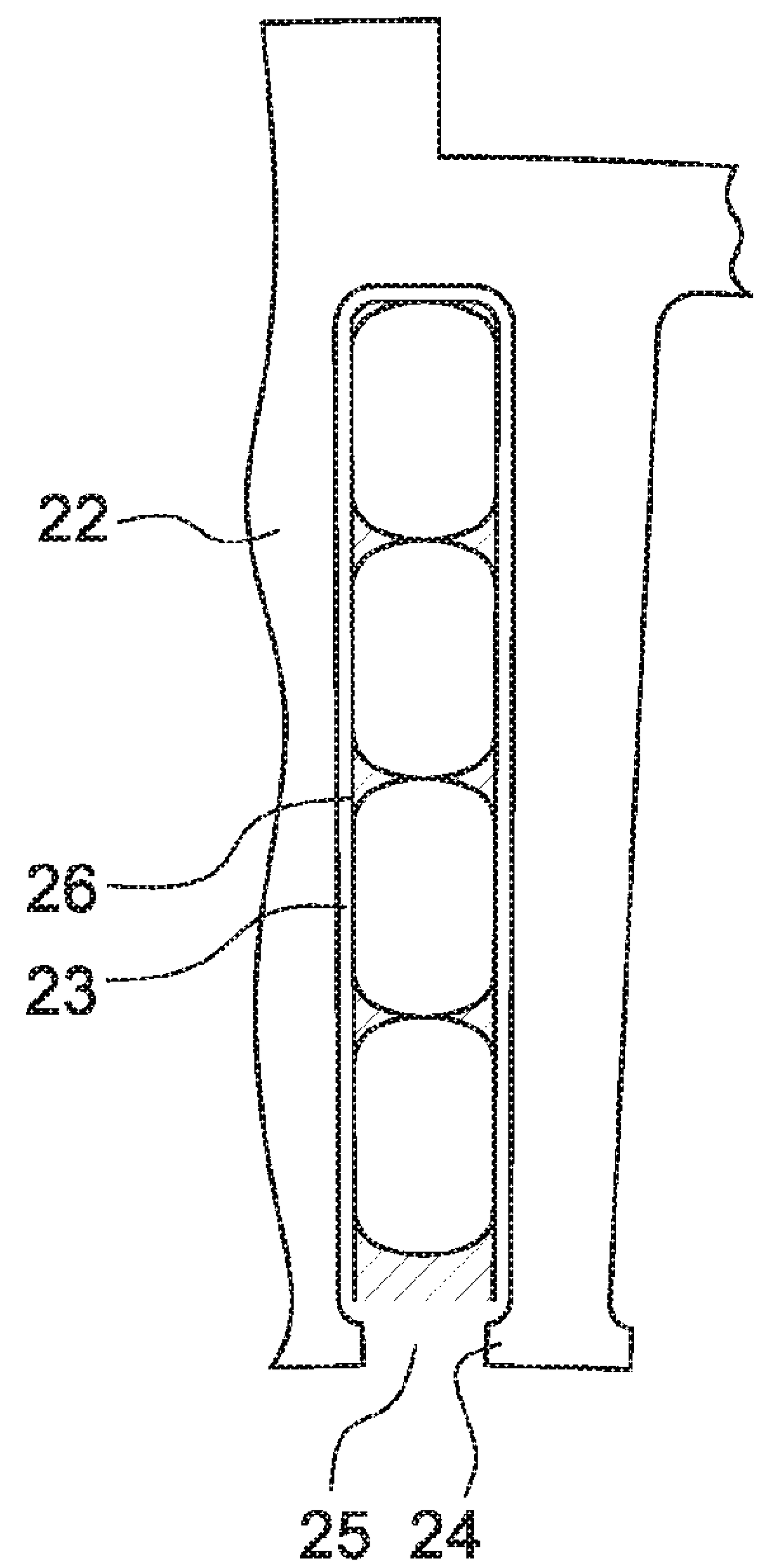


FIG. 7

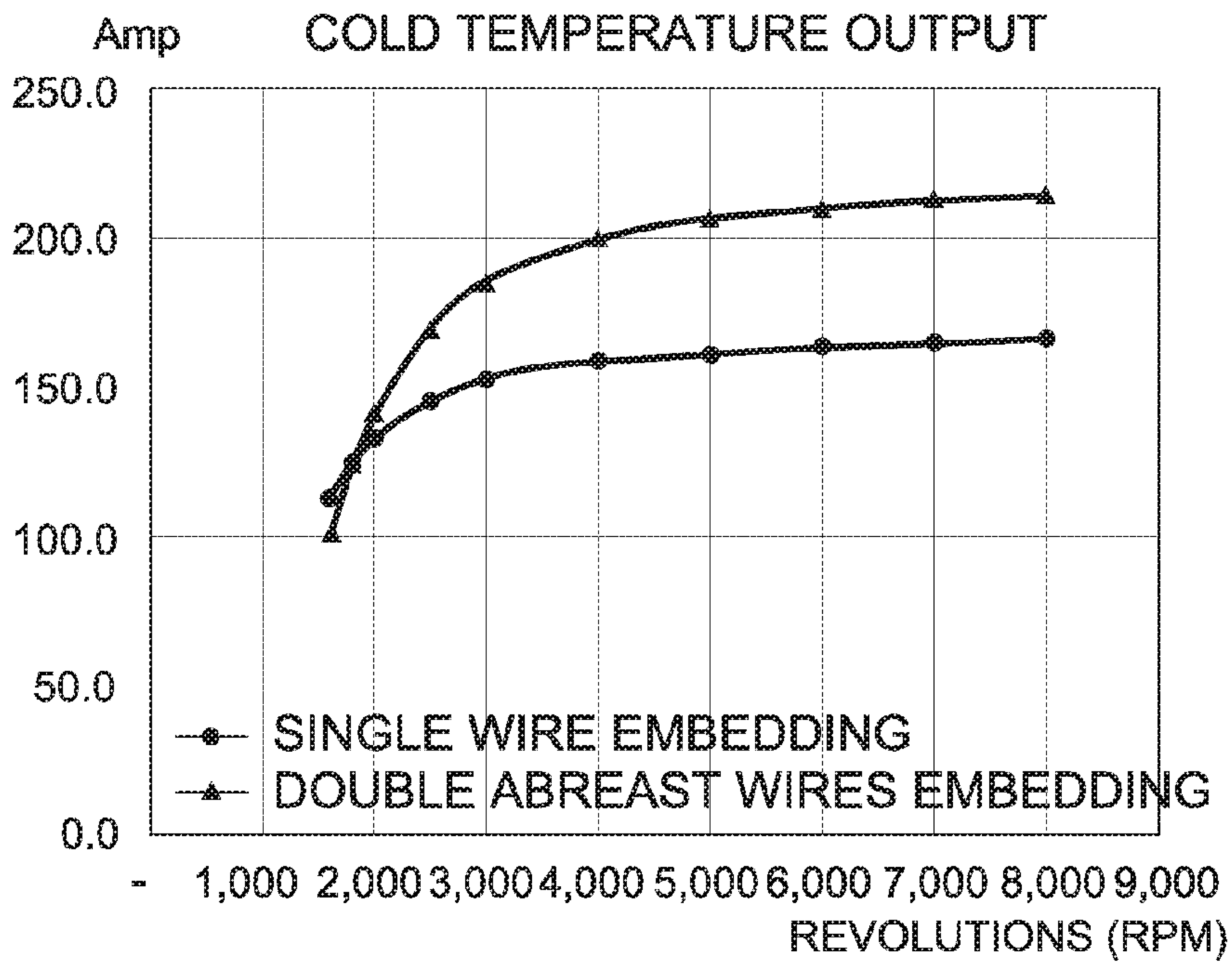

Amp
COLD TEMPERATURE OUTPUT
250.0
200.0
150.0
100.0
50.0
0.0
SINGLE WIRE EMBEDDING
DOUBLE ABREAST WIRES EMBEDDING
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
REVOLUTIONS (RPM)

FIG. 8A

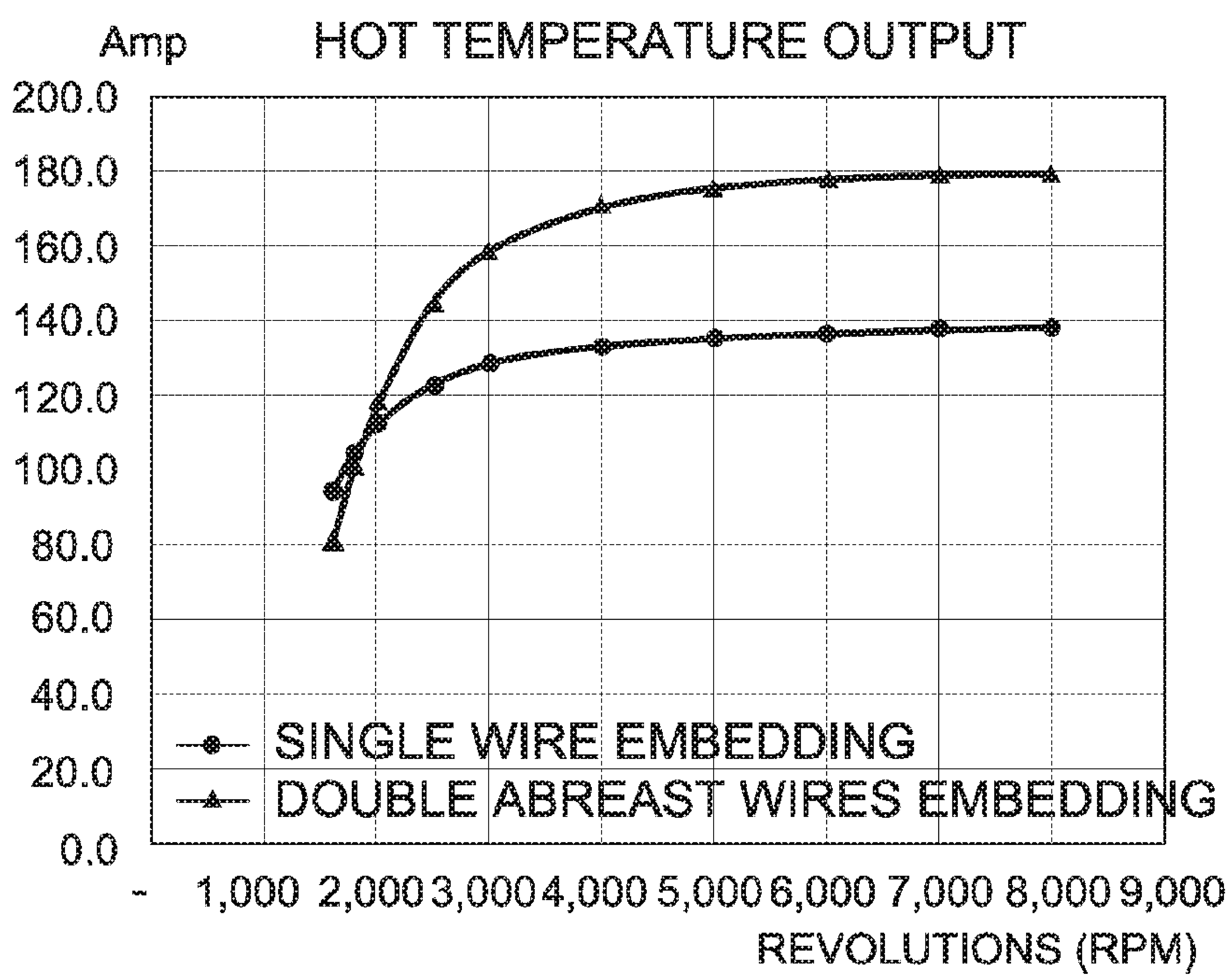

Amp
HOT TEMPERATURE OUTPUT
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
SINGLE WIRE EMBEDDING
DOUBLE ABREAST WIRES EMBEDDING
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
REVOLUTIONS (RPM)

FIG. 8B

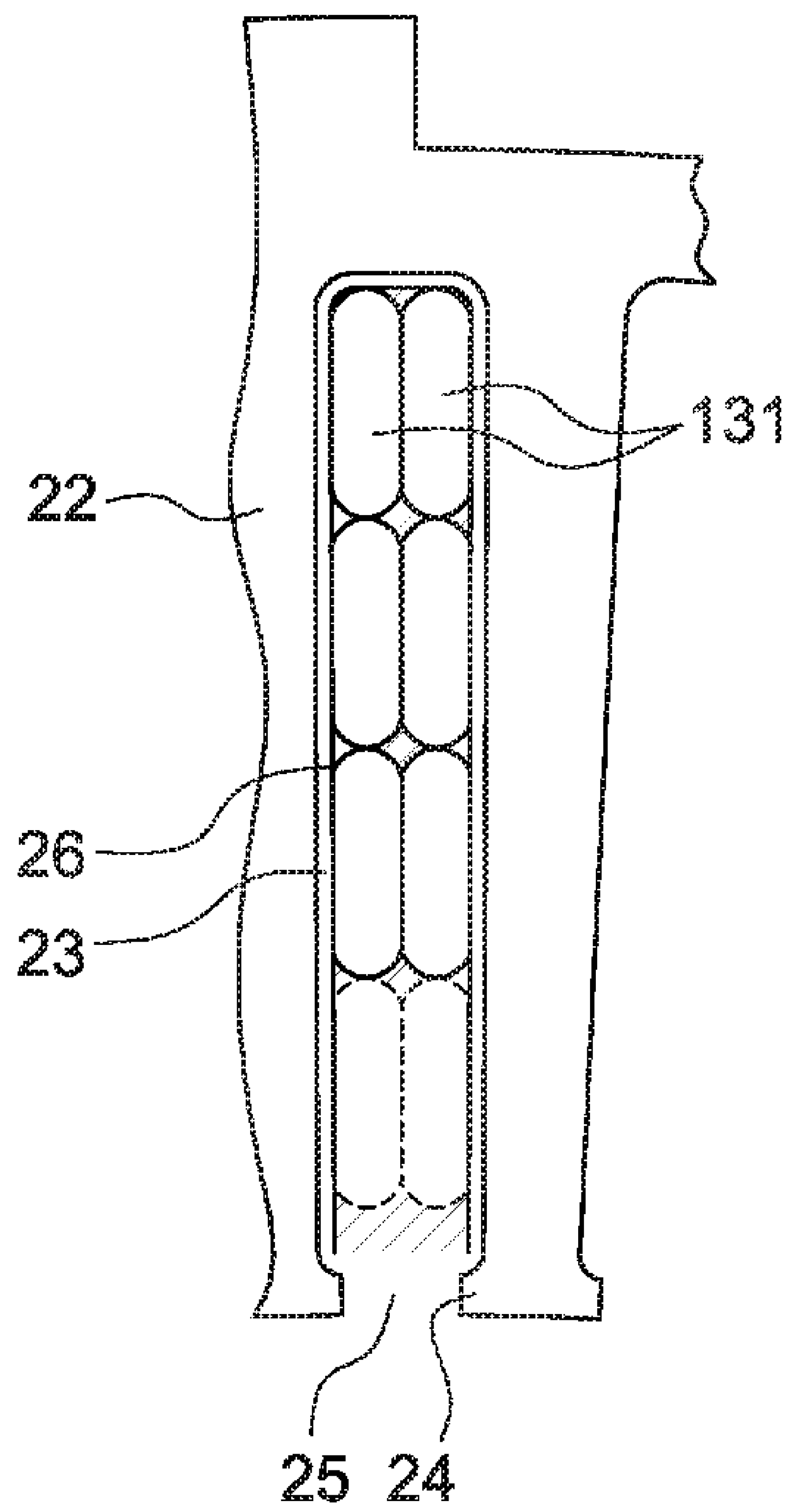


FIG. 9

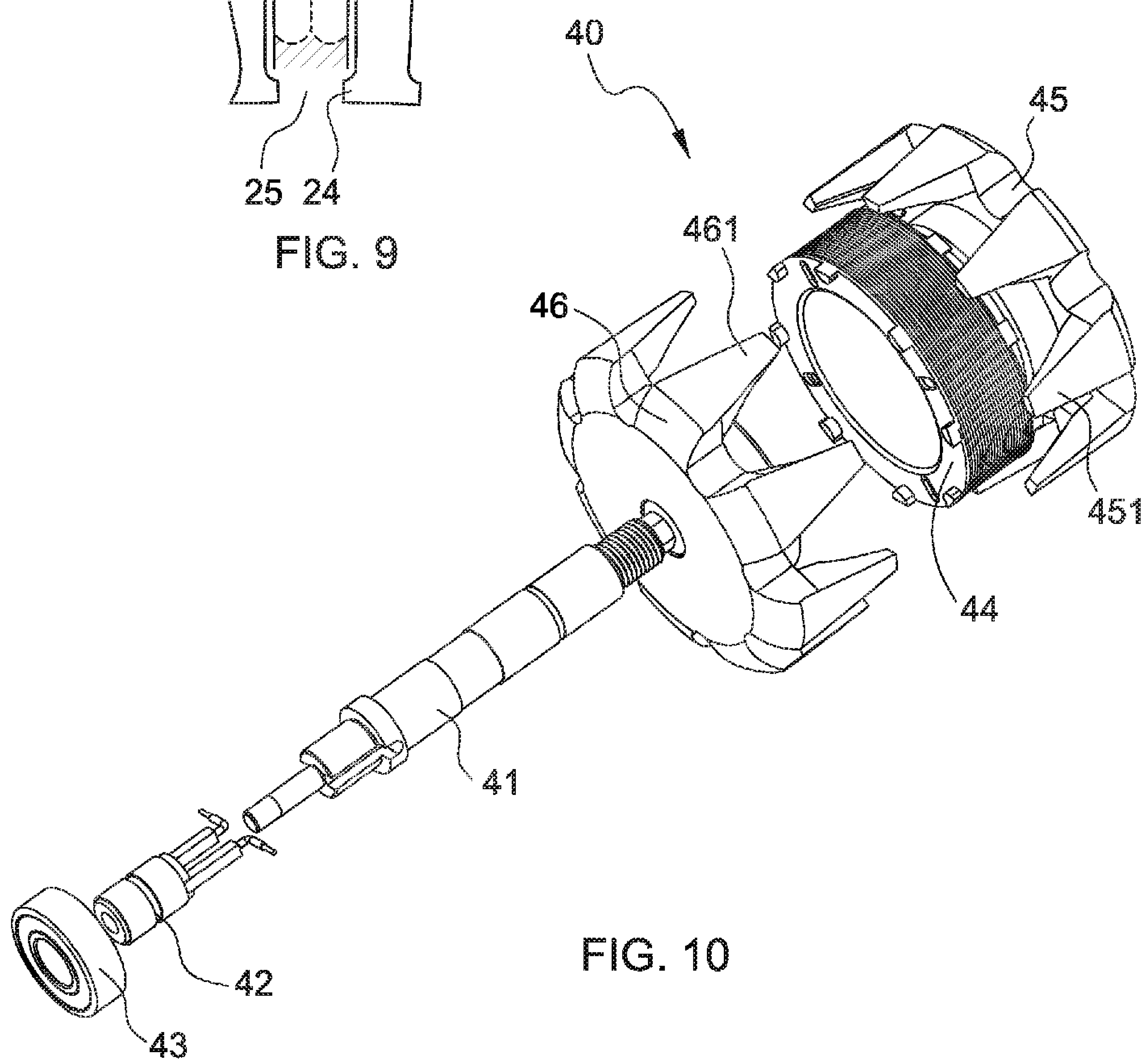


FIG. 10

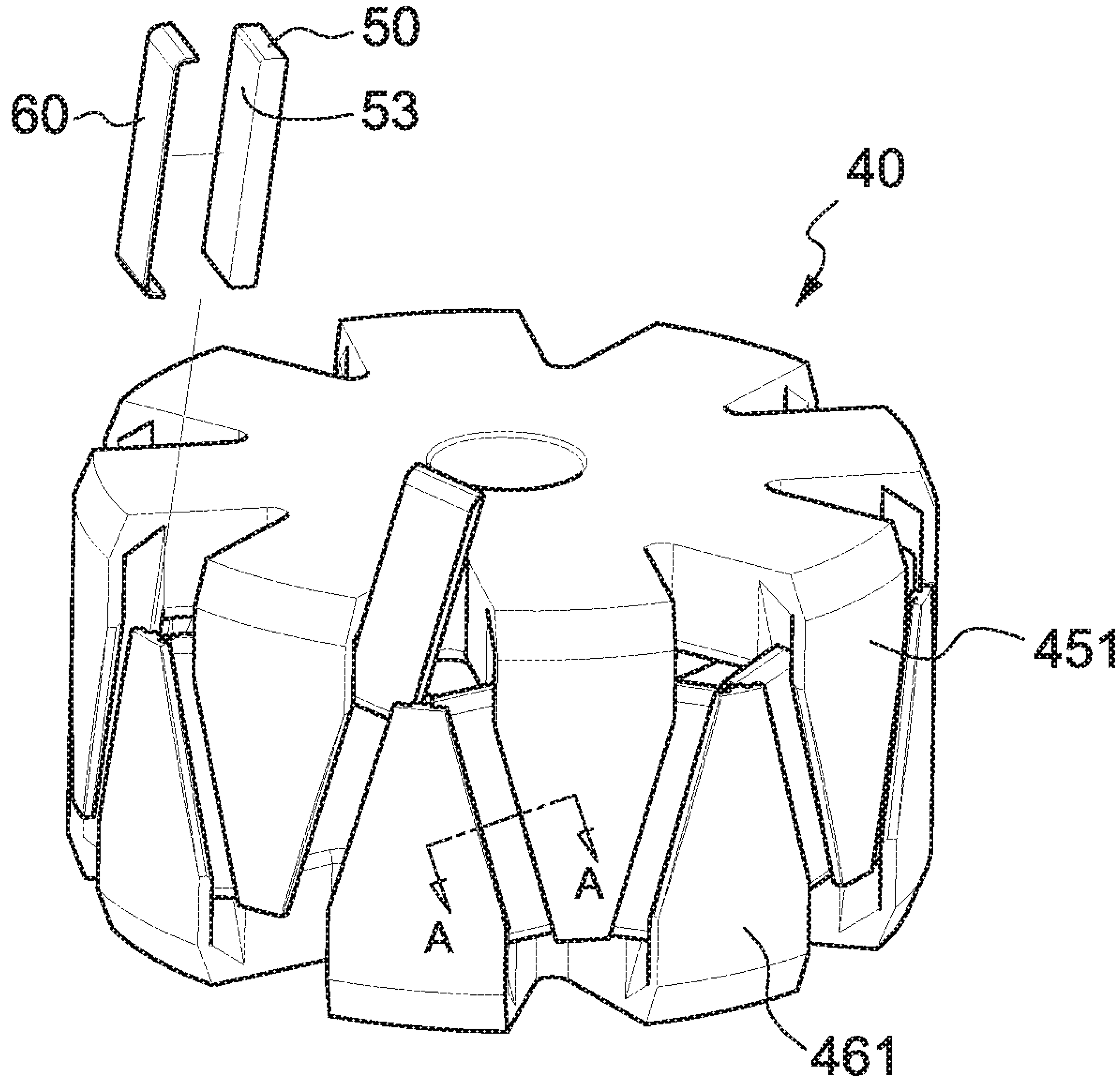


FIG. 11

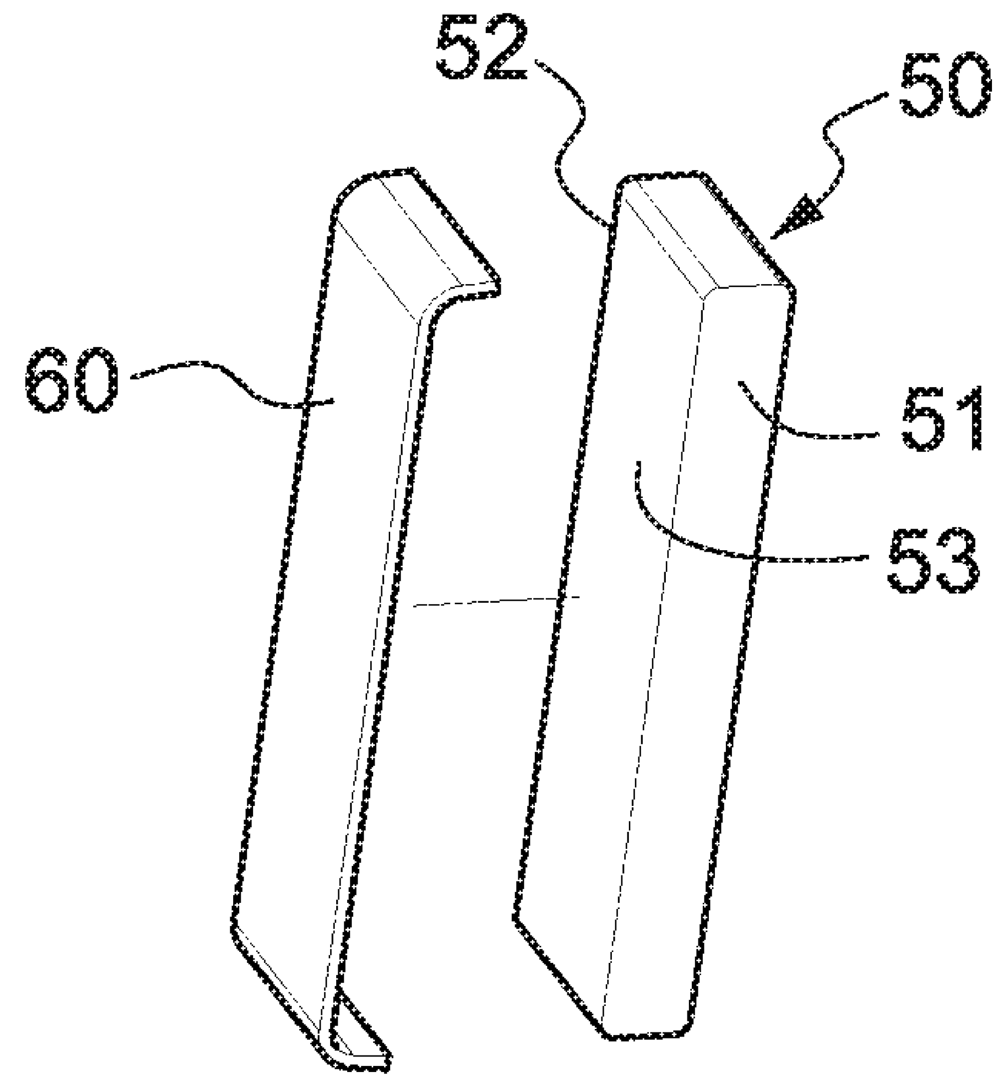


FIG. 12

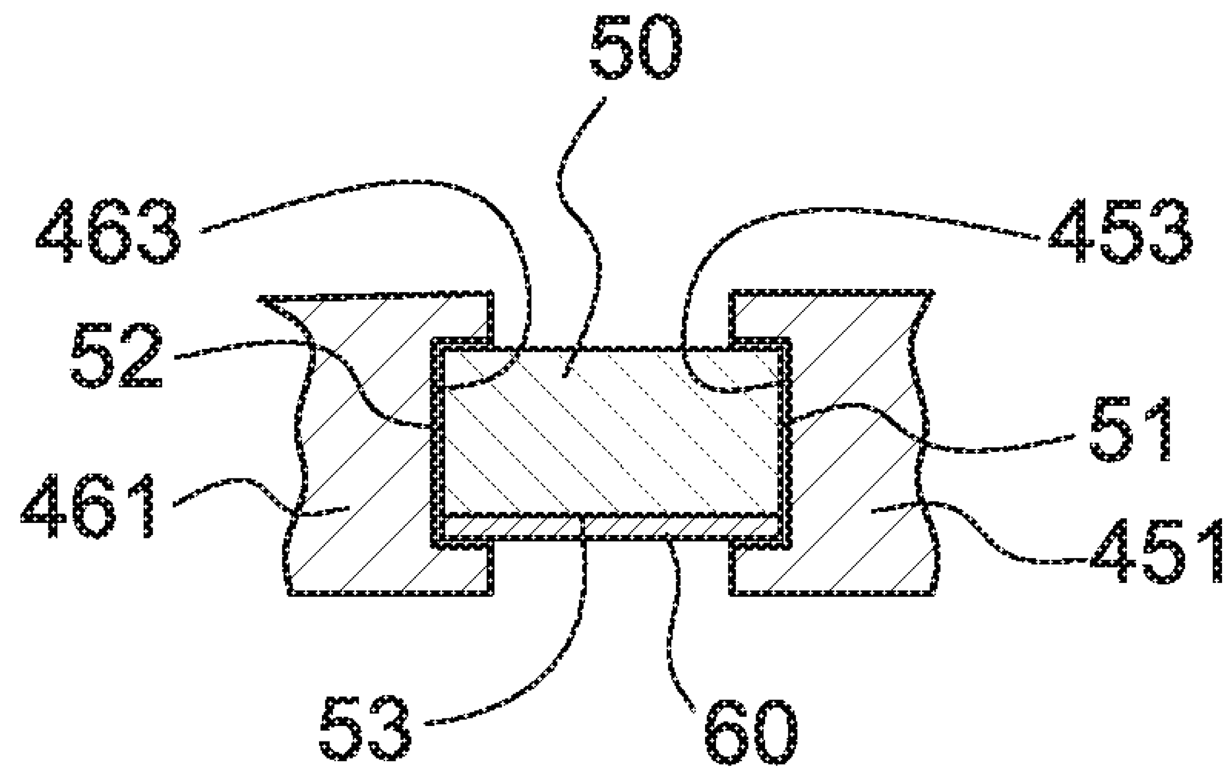


FIG. 13

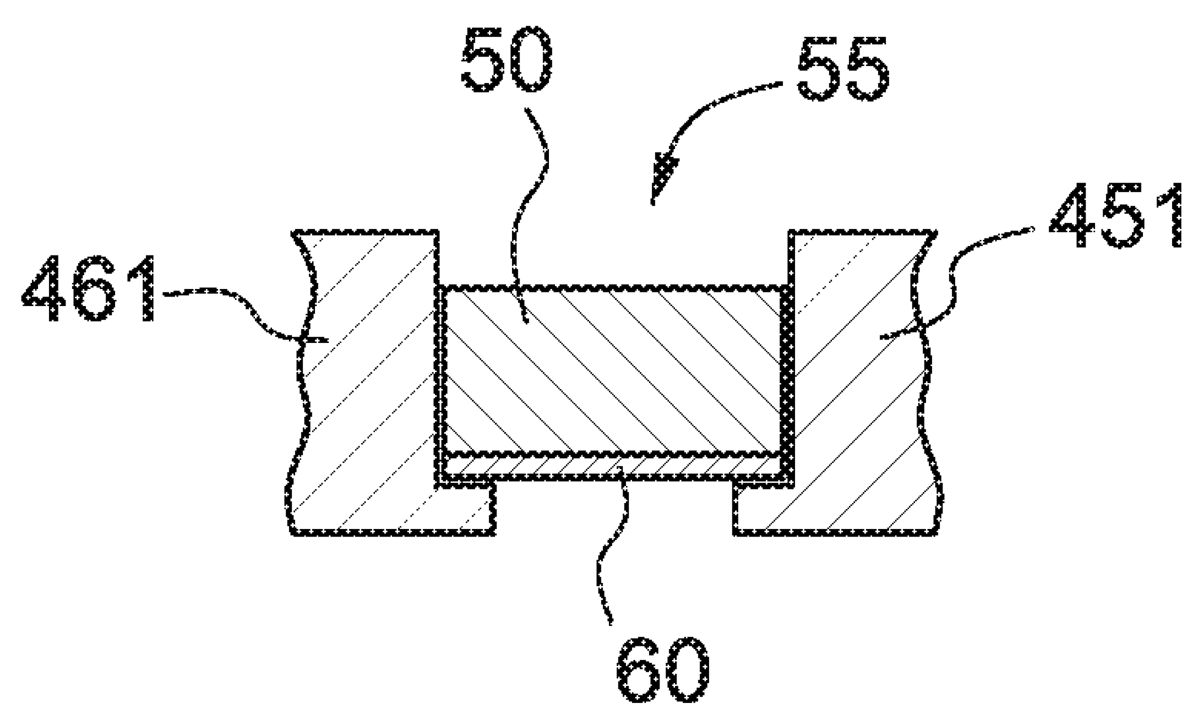


FIG. 14

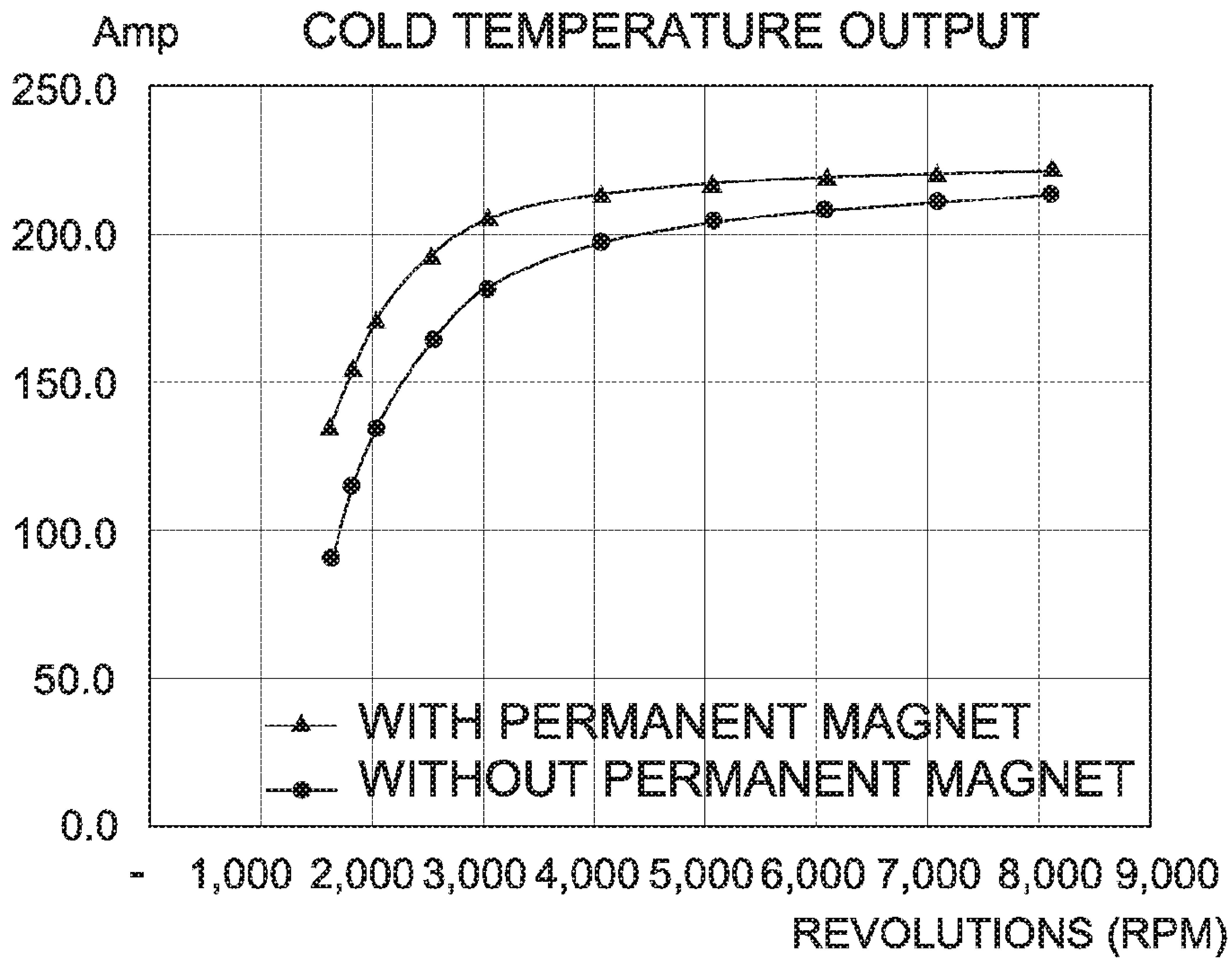


FIG. 15A

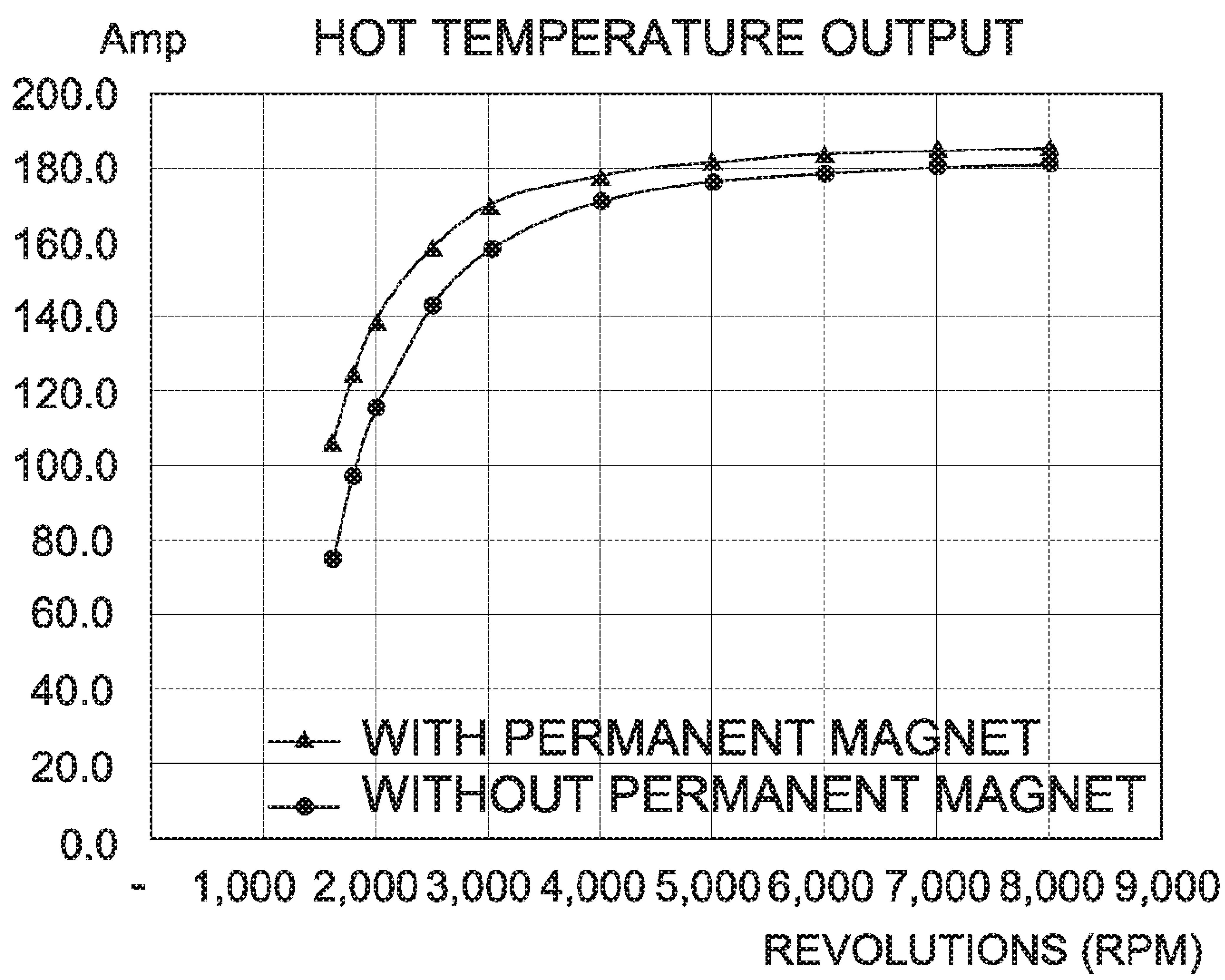


FIG. 15B

WOUND STATOR OF AN ALTERNATOR AND VEHICLE ALTERNATOR

BACKGROUND

Field of the Invention

The present invention relates to a wound stator of an alternator, more particularly to a wound stator of an alternator having double abreast wires embedded in grooves of a stator.

Description of Related Art

An alternator is used for converting mechanical energy into alternating-current electric energy. In a vehicle alternator, the output power of an engine drives a rotor of the generator to rotate within a stator to convert mechanical energy of the engine into electric energy to charge a storage battery, which then supplies electric energy to electrical parts of a vehicle.

A vehicle alternator typically has an annular stator and a rotor. By means of rapid rotation of the rotor in the stator, magnetic fields are formed by wires wound on the stator so as to generate an induced electromotive force (voltage) in the wires. In general, the voltage output by the alternator is proportional to the number of coil groups in a stator ring. Therefore, the higher the density of wires wound on a stator ring, the higher the power generation of the generator.

A variety of coil winding methods have been adopted for a conventional generator, such as folding and winding, or wave-shaped winding. The choice of winding method has an influence on the output voltage of the generator at low rotational speed or high rotational speed resulting in specific output characteristics of an alternator at different rotational speeds. For example, factors concerning the output characteristics of an alternator include the diameter of the conducting wires and the number of wound coils. Under high rotational speed, the output current of the alternator usually increases or decreases along with the wire diameter. Furthermore, under low rotational speed, the output current of the alternator usually increases or decreases along with the number of coils. Therefore, design choices of conducting wire diameter and winding method vary depending upon the desired output characteristics.

Moreover, the stator of an alternator is positioned such that it surrounds the rotor. When the rotor is rotated with respect to the stator, the coils wound on the stator are induced because of electromagnet effect and thus generate alternating current. The rotor normally comprises a first claw pole element and a second claw pole element in which a plurality of the N-pole claw-shaped bodies of the first claw pole element and a plurality of the S-pole claw-shaped bodies of the second claw pole element are respectively adjacent to each other while spaced apart. After an electric current is supplied to the magnetic-field coil of the rotor **1**, a claw pole element of the poles and the other claw pole element can be magnetized into an N pole and an S pole, respectively, due to electromagnetic induction so that each pair of adjacent claw-shaped bodies of the claw pole elements can generate a magnetic field. When the rotor rotates, direction of the magnetic field also changes with rotation of the rotor to further create an electromagnetic induction with the stator coils of the stator to generate an alternating current. However, for a rotor of a generally conventional alternator, after an electric current is supplied to the magnetic-field coil and when the first claw pole element and the second claw pole element of the pole are magnetized into an N pole and an S pole, respectively, due to electromagnetic induction, part of the magnetic lines may directly pass from a space between two adjacent claw-shaped bodies of the claw pole elements and may not participate in formation of the magnetic field of the pole. Such phenomenon is called "magnetic leakage." Magnetic leakage may cause unnecessary magnetic loss and reduce the strength of the magnetic field formed by the pole, which further reduces the generating capacity of the alternator.

In view of the above, optimization of a wire structure and the winding manner as adopted for the wound stator, and also improvement to the rotor structure are desired in order to enhance the output efficacy of an alternator.

BRIEF SUMMARY OF THE INVENTION

An objective of one embodiment of the present invention is to provide a wound stator of an alternator having improved output efficacy.

Another objective of another embodiment of the present invention is to provide a combined wound stator and rotor structure of an alternator having improved output efficacy.

An embodiment of the present invention discloses a wound stator of an alternator, comprising: a stator; and a group of wires for a stator comprising a plurality of abreast wires arranged in a radial direction, wherein the group of wires for a stator are embedded in corresponding grooves of the stator sequentially.

Another embodiment of the present invention discloses a wound stator for an alternator. The wound stator comprises: a stator and two abreast wires wherein the stator has a plurality of radial grooves arranged at an inner circumference of the stator and each of the two abreast wires comprises a first end, a second end and a plurality of wave-shaped coils located between the first end and second end. Each wave-shaped coil is formed of straight portions and curved portions that alternate with each other, wherein each of the wires is pressed so that the cross section of the straight portions is of a generally elliptical shape. The straight portions of the two abreast wires are sequentially embedded in corresponding grooves of the stator and the two abreast wires in the grooves are oriented in a direction along the circumferential direction of the stator.

A further embodiment of the present invention discloses an alternator for a vehicle, comprising: a wound stator of an alternator according to the above embodiments, a rotor comprising a first claw pole element and a second claw pole element opposite thereto, wherein the first claw pole element has a plurality of N-pole claw-shaped bodies, the second claw pole element has S-pole claw-shaped bodies in which the number of the N-pole claw-shaped bodies is the same as that of the S-pole claw-shaped bodies, wherein when the first claw pole element and the second claw pole element are combined with each other, the plurality of N-pole claw-shaped bodies of the first claw pole element and the plurality of S-pole claw-shaped bodies of the second claw pole element are respectively adjacent to each other while spaced apart; wherein a permanent magnet is fixedly disposed between at least one N-pole claw-shaped body of the first claw pole element and its adjacent S-pole claw-shaped body of the second claw pole element, wherein an N polar end of the permanent magnet is in contact with the N-pole claw-shaped body of the first claw pole element, and an S polar end of the permanent magnet is in contact with the S-pole claw-shaped body of the second claw pole element, wherein the rotor is coaxially arranged within the wound stator of the alternator.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a wire for a stator according to an embodiment of the present invention;

FIG. **2** is a schematic view of a wire template for fabricating a wire for a stator;

FIG. **3**A is a schematic top view of a flattening jig;

FIG. **3**B is a schematic side view of the flattening jig;

FIG. **3**C is a schematic side view showing that the wires are flattened by the flattening jig;

FIG. **4**A is a schematic view of a stator ring according to an embodiment of the present invention;

FIG. **4**B is a partially enlarged view of FIG. **4**A;

FIG. **5**A is a schematic view of a stator winding according to an embodiment of the present invention, which shows double abreast wires disposed in a radial direction and embedded into each groove of a groove group of first phase in a forward direction;

FIG. **5**B is a schematic view of a stator winding according to an embodiment of the present invention, which shows that after the double abreast wires are embedded into each groove of the groove group in the forward direction in FIG. **5**A, they are embedded therein in a reverse direction;

FIG. **6** is a partial, sectional view of a wound stator according to an embodiment of the present invention having double abreast wires of small diameter disposed in a radial direction and embedded into a groove of the stator;

FIG. **7** is a partial, sectional view of a wound stator having single wire of large diameter embedded into a groove of the stator;

FIG. **8**A is a graph of cold temperature output drawn according to Table 1 in the specification.

FIG. **8**B is a graph of hot temperature output drawn according to Table 1 in the specification.

FIG. **9** is a partial, sectional view of a wound stator according to an embodiment of the present invention having double abreast wires embedded in a groove of the stator wherein the double abreast wires are oriented along the circumferential direction of the stator;

FIG. **10** is an exploded view of a rotor of an alternating-current generator according to an embodiment of the present invention;

FIG. **11** is a schematic view showing magnetic poles of a rotor for an alternator according to an embodiment of the present invention;

FIG. **12** is schematic view showing a permanent magnet and its cover according to an embodiment of the present invention;

FIG. **13** is a sectional view taken along Line A-A in FIG. **11** in which the permanent magnet and its cover are mounted to the poles according to an embodiment of the present invention;

FIG. **14** is a sectional view taken along Line A-A in FIG. **11** in which the permanent magnet and its cover are mounted to the poles according to another embodiment of the present invention;

FIG. **15**A is a graph of cold temperature output drawn according to Table 2 in the specification; and

FIG. **15**B is a graph of hot temperature output drawn according to Table 2 in the specification.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

The characteristics, subject matter, advantages, and effects of the present invention are detailed hereinafter by reference to embodiments of the present invention and the accompanying drawings. It is understood that the drawings referred to in the following description are intended only for purposes of illustration and do not necessarily show the actual proportion and precise arrangement of the embodiments. Therefore, the proportion and arrangement shown in the drawings should not be construed as limiting or restricting the scope of the present invention.

FIG. **1** is a schematic view of a wave-shaped wire for a stator of a vehicle alternator according to one embodiment of the present invention. As shown in FIG. **1**, a wire **10** includes a first end **11**, a second end **12**, and a plurality of wave-shaped coils **13** located between the first end **11** and the second end **12**, and each wave-shaped coil **13** is formed by a plurality of straight portions **131** and a plurality of curved portions **132** that alternate with each other. For example, a wave-shaped coil **13** may be regarded as one sine shape formed of a straight portion(s) **131** and a curved portion(s) **132**. The number of wave-shaped coils of the wire **10** may also be regarded as, for example, the number of curved portions **132** that open downwards in FIG. **1** (in FIG. **1**, there are 8 curved portions **132** which can be regarded as 8 coils). The number of wave-shaped coils of the wire **10** may be 6 to 8, or may be a larger number of turns, for example, 12 to 16. For the material of the wire **10**, an enameled copper with a circular cross section is typically used. Alternatively, to increase wire density after the stator is assembled, the straight portion **131** of the wire **10** may be pressed flat by using a jig, making the cross section of the straight portion **131** into a square shape, a rectangular shape, an elliptic shape or the like. In the present embodiment, the straight portions **131** of the wire **10** are flattened to form generally an elliptical cross section having opposed flat sides (as shown in FIG. **3**C). The advantage of such an approach lies in that, compared with an approach in which a flat wire is used to increase wire density in a stator groove (to reduce an air gap ratio), the cost of using a flat copper wire is much higher than that of using a common round copper wire that is partially pressed flat later. This is because when a wire is wound in a stator groove, a curved part that is not in the stator groove does not have an air gap ratio problem; the use of a partially flattened wire of the present invention can not only achieve the same effects of increasing wire density and lowering air gap ratio between wires as using a flat wire but it also effectively saves manufacturing cost. Certainly, a flat wire can be directly used to pursue desirable power generation efficacy. In this case, the cross sections of both the straight portion **231** and curved portion **232** would have a square shape, a rectangular shape, an elliptic shape or the like with flat sides.

Furthermore, the wire **10** with the desired shape may be implemented by using a wire template **800**, such as the one shown in FIG. **2**. In a manufacturing process of the wire, a long and straight wire is bent along shaped contours of wire template bumps **810** and winds through gaps **820** in the wire template bumps **810** in an alternative manner. Since the contours of the wire template bumps **810** have shapes that conform to those of the straight portion **131** and the curved portion **132** of the wire **10**, through the above manufacturing process, the desired wave-shaped coils **13** having the straight portions **131** and the curved portions **132** that alternate with each other are formed.

Further, after the wire **10** is finished, a flattening jig may be used to implement flattening of the straight portions **131** to make the cross sections of the straight portions **131** into a noncircular shape, for example, as shown by the flattening jig **900** in FIG. **3**A to FIG. **3**C. FIG. **3**A is a top view of a flattening jig **900**, which has clamping grooves **910** to receive the straight portions **131** of the wire **10**. Further, as shown in FIG. **3**B, the straight portions **131** (circular cross sections) of the wire **10** may be placed inside the clamping grooves **910** of the flattening jig **900** and the wire **10** may be pressed from its sides to be flattened into the required shape or size, so as to obtain the flattening forms of the straight portions **131** of the wire **10** shown in FIG. **3**C (i.e., a generally elliptical-shaped cross section having opposite flat sides); in this case, the wire **10** is a partially flattened wire in which the curved portions **132** remain round in shape.

FIG. **4**A is a stator structure according to one embodiment of the present invention. As shown in FIG. **4**A, a stator **20** has an annular body **21**, where a plurality of radial elongated grooves **23** separated by separating posts **22** is formed at an inner circumference of the stator. The number of grooves **23** is, but is not limited to, for example, 72 to 96 (96 grooves in FIG. **4**A). An end of the separating post **22** slightly protrudes from its two adjacent sides to form a magnetic shoe **24**, and an opening **25** of the groove **23** is formed between two magnetic shoes **24**. Generally speaking, the stator **20** is made of a material with desirable electrical and magnetic field properties, for example, cold-rolled steel plate (SPCC), silicon steel or other similar materials. An electrical insulating material **26** may be laid on the surface of the elongated groove **23** of the stator. As shown in FIG. **4**B, for the electrical insulating material **26**, a sheet-form material is folded to fit the shape of the surface of the radial elongated groove **23** inside the stator **20** and is directly embedded in the groove **33** to cover the surface of the groove **33**. The electrical insulating material **26** can be made of a material such as pressed paper board, plastic film, polyester film, aramid paper, and epoxy resin.

The plurality of elongated grooves **23** of the stator **20** are used for the winding of the wire **10**. In particular, each straight portion **131** of the wave-shaped coil **13** of the wire **10** is, starting from the first end **11** of the wire **10**, sequentially embedded in the corresponding grooves **23** of the stator **20** and juts out from one of the corresponding grooves with the second end **12** of the wire **10**. In this case, the groove **23** has one embedded layer of the wire **10**. A plurality of layers of the wire **10** may be embedded in the same groove to increase power generation. The winding work for the stator **20** is completed by embedding multiple wave-shaped wires **10** in all the grooves **23** of the stator **20**, such that each groove **23** has embedded wires. The details of the winding work for the stator **20** are further illustrated below by way of an explanatory embodiment according to the present invention.

In FIG. **5**A and FIG. **5**B, a wave-shaped wire **10** for winding a stator **20** of the present invention is used. This embodiment shows how to fabricate a wound stator having two sets of three-phase power generations. As shown in FIGS. **4**A and **4**B, a stator **20** having 96 grooves is provided. For each phase of power generation, two windings and 32 grooves **23** are involved, and for each winding, 16 grooves are involved. In other words, if the 1^{st} and 2^{nd} grooves and corresponding grooves (that is, the 7^{th} and 8^{th} grooves, 13^{th} and 14^{th} grooves, . . . , 91^{st} and 92^{nd} grooves) are for a first phase, the 3^{rd} and 4^{th} grooves and corresponding grooves (that is, the 9^{th} and 10^{th} grooves, 15^{th} and 16^{th} grooves, . . . , and 93^{th} and 94^{th} grooves) are for a second phase, and the 5^{th} and 6^{th} grooves and corresponding grooves (that is, the 1^{th} and 12^{th} grooves, 17^{th} and 18^{th} grooves, . . . , and 95^{th} and 96^{th} grooves) are for a third phase. In this case, the 96 grooves **23** form a circle around the stator **20**.

As shown in FIG. **5**A, a pair of abreast wave-shaped wires **10***a* and **10***b* are disposed in the radial direction of the stator **20**. The abreast straight portions **131***a* and **131***b* of the wires **10***a* and **10***b* are, starting from first ends **11***a* and **11***b* of the wires **10***a* and **10***b*, simultaneously embedded in the 1^{st} groove from one of the plurality of grooves **23** (annotated in FIG. **4**B) of the stator **20** wherein the straight portions **131***a* and **131***b* are radially adjacent to each other in the 1^{st} groove. In this embodiment, the groove corresponding to the ends **11***a* and **11***b* of the wire **10***a* and **10***b* as shown in FIG. **5**A is designated as the 1^{st} groove. Next, each pair of the abreast straight portions **131***a* and **131***b* of the wires **10***a* and **10***b* are sequentially and radially embedded in a forward direction (e.g. clockwise) in the 7^{th} groove, 13^{th} groove, 19^{th} groove, 25^{th} groove, . . . until the 91^{st} groove to complete the winding of the wire around the entire circumference of the annular body **21** of the stator **20**. When the abreast wires **10***a* and **10***b* jut out from the 91^{st} groove (the groove corresponding to the arrow A in FIG. **5**A), 8 coils out of the 16 coils of the wires **10***a* and **10***b* are left outside the grooves (not shown). Next, referring to FIG. **5**B, the rest of the abreast straight portions **131***a* and **131***b* of the wires **10***a* and **10***b* outside the grooves, starting from the 91^{st} groove, are radially embedded in a reverse direction (direction of arrow A; i.e., counterclockwise) in the corresponding grooves **33** that already have double abreast wires embedded therein from the forward winding, and after reverse winding around the entire circumference of the stator **20**, the second ends **12***a* and **12***b* of the wires **10***a* and **10***b* jut out from the 91^{st} groove. In this way, the abreast wires **10***a* and **10***b* disposed in the radial direction wind around the stator **20** by two turns (one turn in the forward direction and the other in the reverse direction) to complete the winding of a set of wires for one phase (i.e., the grooves into which the wires **10***a* and **10***b* are embedded after winding form a winding set of one phase), and four wire ends, that is, the first ends **11***a* and **11***b* adjacent to each other in the radial direction, as well as the second ends **12***a* and **12***b* adjacent to each other in radial direction, are left outside the grooves **23** of the stator **20**. Subsequently, based on the foregoing manner, double abreast wires **10** disposed in the radial direction are sequentially embedded in the next two groups of grooves (the 3^{rd} and 4^{th} grooves and the corresponding grooves) for the second phase and the further next two groups of grooves (the 5^{th} and 6^{th} grooves and the corresponding grooves) for the third phase so as to complete a stator winding having three phases of power generation windings; in this embodiment, each groove **23** of the stator **20** has a total of four layers of straight portions of the wires.

However, to increase power generation and enhance power generation efficacy, the grooves **23** of the stator **20** are not limited to receiving only four layers of the straight portions of the wires. For example, according to another preferred embodiment, in the foregoing groove set for the first phase and in the groove where the second ends **12***a* and **12***b* of the wires **10***a* and **10***b* respectively jut out, the first ends of an additional two of the same abreast wires **10** each having 8 coils are arranged in the radial direction and are respectively connected in series to the forgoing second ends **12***a* and **12***b*. Then, beginning with the first ends of the additional two wires **10**, the abreast straight portions of the additional two wires disposed in the radial direction start to be embedded in the corresponding grooves in a forward direction around the entire circumference of the stator **20** from the 1^{st} groove to the 91^{st} groove, and jut out from the 91^{st} groove. Accordingly, each groove of one groove group corresponding to the first phase of the stator **20** can have six layers of wires embedded therein, and four wire ends, that is, the first ends **11***a* and **11***b* of the wires **10***a* and **10***b* and the second ends of the additional two wires. Subsequently, based on the foregoing manner, additional wires can be further embedded in the other group of the grooves for the first phase, in the next two groups of grooves for the second phase and in the further next two groups of grooves for the third phase, so as to complete a stator winding having two sets of three phases of power generation windings with each groove **23** having six layers of straight portion **131** of wire **10** embedded therein. Finally, after the wire ends of the same phase are soldered, the wires for the three phases are further soldered in a Y-connection or in a connection of a star shape to complete the wire connection of the wound stator having six layers of wire.

The number of layers of wires **10** in a groove **23** of a stator **20** of the present invention is not limited to the four or six layers of wires as mentioned in the above embodiments. For example, if the above-mentioned additional abreast wires arranged in the radial direction which have 8 coils are replaced by the wires having 16 coils, each groove of the stator **20** would have 8 layers of wires after winding. If necessary, by increasing the depth of the groove **23**, the number of double abreast wires **10** arranged in the radial direction and embedded in a groove group of one phase can be increased to, for example, 4 to 16 layers of wires. In this case, power generation efficacy can be enhanced rapidly and effectively.

Further, the wire **10** as adopted in the embodiments of the present invention is not limited to a wire having 16 coils. A wire having 8 coils may be used instead. For example, for the winding in a phase in which a groove of a stator **20** has four layers of wire, four wires having 8 coils are required.

In contrast, if conventional 1.9 mm diameter wires are used, the straight portions thereof after being pressed forms a cross section of a generally elliptical shape having a major axis length of about 2.3 mm to 2.4 mm and a minor axis length of 1.4 mm. With the same groove width and depth, the groove **23** of the stator **20** can only receive 4 layers of such wires as shown in FIG. **7**. The straight portions of a single wire, starting from the first end of the wire, are sequentially embedded in the corresponding grooves **23** of the stator **20** and wound around the stator **20** in the sequence of forward direction-reverse direction-forward direction-reverse direction so as to complete the winding to form a wound alternator stator having two sets of three phase windings with each groove of the wound stator having 4 layers of wires.

As mentioned above, the factors influencing the output efficacy of an alternator include the wire diameter and the number of coils as wound (i.e., the number of wire layers in the groove). Tests of cold temperature output and hot temperature output under different revolutions are conducted on the same rotor respectively combined with a wound stator having double abreast wires of 1.5 mm diameter embedded therein (see FIGS. **5**A, **5**B and **6**), and with a wound stator having a single wire of 1.9 mm diameter embedded therein (see FIG. **7**). The results are shown in the following Table 1:

TABLE 1

		Rev(rpm)									
Amp		1,600	1,800	2,000	2,500	3,000	4,000	5,000	6,000	7,000	8,000
Cold temp. output	Single wire embedding	113.3	124.8	132.8	145.3	152.0	158.1	161.2	163.4	164.9	165.6
	Double abreast wire embedding	101.9	124.2	141.9	170.0	185.8	200.3	206.8	210.6	213.0	215.1
Hot temp. output	Single wire embedding	94.3	104.7	112.1	122.7	128.5	133.0	135.3	136.6	137.5	138.0
	Double abreast wire embedding	80.9	100.7	118.0	144.0	158.6	170.4	175.5	177.9	179.0	178.9

As shown in the embodiment of FIG. **6**, the two opposed flat sides of the flattened straight portions of each of the double abreast wires **10**a, **10**b are embedded in the groove **23** along the radial direction of the groove **23** so that the orientation of the double abreast wires **10**a, **10**b is along a radial direction of the groove **23**. It can be seen from FIG. **6** that the groove **23** of the stator **20** comprises 6 layers of wire (i.e., 3 layers of the double abreast straight portion of the wires arranged in the radial direction). The advantage of the winding disclosed in FIGS. **5**A and **5**B lies in allowing wires with a diameter smaller than the diameter of the conventional wires (e.g., conventional wire diameter of 1.9 mm) to be used so that more layers of wires can be embedded in the groove **23** of the stator to enhance the output performance of the alternator under high revolutions. For example, if enameled copper wires with 1.5 mm diameter are used, the straight portions thereof after being pressed form a cross section of a generally elliptical shape having a major axis length of 1.6 mm and a minor axis length of 1.4 mm, and therefore 6 layers of such pressed wires in the groove **23** are filled in the groove **23** to form the structure shown in FIG. **6**. Of course, the present invention is not limited to the use of the wire with 1.5 mm diameter for the double abreast wires **10**a, **10**b. Those wires with other smaller diameters (such as 1.7 mm, 1.6 mm and so on) are also workable.

The cold temperature output shown in Table 1 is measured directly at the beginning of testing for the stator in combination with the rotor; the hot temperature output is measured at about 40 to 50 minutes after the test for the stator in combination with the rotor has begun. The temperature of the stator is higher under hot temperature test than it is under cold temperature test. The condition under hot temperature test is closer to the actual working condition of the alternator. In view of Table 1, a comparison between the wound stator shown in FIG. **6** with double abreast wires of 1.5 mm diameter embedded therein and the wound stator shown in FIG. **7** with single wire of 1.9 mm diameter embedded therein reveals that both the hot and cold temperature output of the former are always greater than those of the latter when the revolutions of the rotor are higher than 2,000 rpm. That is, the current output efficacy of the former is better than the latter under high revolutions. As shown in the cold temperature output graph of FIG. **8**A, and the hot temperature output graph of FIG. **8**B, the wound stator having double abreast wires embedded therein with pressed wires of small diameter (e.g., 1.5 mm) has better output efficacy than the wound stator having a single wire embedded therein with conventional wires such as a wire of 1.9 mm diameter.

Further to the above, the size of the magnet shoes formed at the end of the separating posts **22** can be reduced so as to increase the dimension of the openings **25**. As shown in FIG. **6**, in the present invention, the width of the groove **23** of the stator **20** is designed to allow receiving only one single wire **10**, and therefore the groove width of the groove **23** is slightly larger than the diameter of the wire **10**. In addition, the end of the separating post **22** has a magnetic shoe **24** of a reduced size makes the width of the groove opening **25** close to the width of the groove **23** so that the straight portion **131** of the wire **10** can be directly and completely embedded in the groove **23** from the opening **25**. As for the efficacy of power generation, surprisingly, after winding is completed according to the above embodiment of the present invention, the power generation efficacy is close to the case where the size of a magnetic shoe is larger.

The advantage of the foregoing stator structure in which the size of the magnetic shoe **24** of the stator **20** is decreased to increase the dimension of the opening **25** of the groove **23** according to the present invention is that: it is easy for the entire straight portion **131** of the wire **10** to be directly embedded in the groove **23**, thereby significantly lowering the complexity of winding, increasing the winding speed, and making possible automatic winding by using a lead-in wire jig. Thus, production efficiency is improved.

The structure of the wound stator with double abreast wires embedded therein as disclosed in this application is not limited to that shown in FIGS. **5**A, **5**B and **6**. In an alternative approach as shown in FIG. **9**, the double abreast wires **131** are disposed adjacent to each other and thus is oriented in a circumferential direction of the stator. The straight portions of double abreast wires are, starting from the first end, sequentially embedded in a forward direction in the corresponding grooves of the stator to surround the stator in a manner and are then sequentially embedded in the corresponding grooves of the stator in a reverse direction to surround the stator so that each of the corresponding grooves has two radial layers of wires disposed adjacent to each other in the circumferential direction. Similarly, the above double abreast wires can be further respectively connected in series to the first end of another double abreast wires, and the straight portions of the other double abreast wires are disposed adjacent to each other in a circumferential direction of the stator and are, starting from the first end thereof, sequentially embedded in a forward direction in the corresponding grooves of the stator to surround the stator and jut out with the second end of the other double abreast wires so that each of the corresponding grooves has three radial layers of wires adjacent to each other in the circumferential direction. In another embodiment, the forgoing double abreast wires with three radial layers of wires embedded in the grooves of the stator are then sequentially embedded in the corresponding grooves of the stator in a reverse direction and jut out with the second end of the other two wires so that each of the corresponding grooves has four radial layers of wires adjacent to each other in the circumferential direction.

A wound stator as illustrated in the above may be combined with a rotor **40** as shown in FIG. **10** to form a vehicle alternator assembly. The rotor **40** of the alternator is rotatable relative to the stator (not shown). The rotor **40** includes a rotating shaft **41**, a slip ring **42**, a bearing **43**, a magnetic field coil **44**, a first claw magnetic pole element **45**, and a second claw magnetic pole element **46**. The wound stator surrounds the rotor **40** in coaxial form. When electric power from a vehicle storage battery is supplied to the magnetic field coil **44** through the slip ring **42**, the first claw magnetic pole element **45** and the second claw magnetic pole element **46** are magnetized under the effect of electromagnetic induction to generate a magnetic field. When the rotor **40** is driven by power from an engine to rotate relative to the wound stator, the direction of the magnetic field also changes with the rotation of the rotor **40**. In that case, the stator coil generates an alternating current via electromagnetic induction.

In particular, when a current is passed through the magnetic field coil **44** of the rotor **40**, the first claw magnetic pole element **45** and the second claw magnetic pole element **46** may be magnetized into an N pole and an S pole due to electromagnetic induction. As such, the claw-shaped bodies **451**, **461** of each pair of adjacent claw magnetic pole elements **45**, **46** may produce a magnetic field. During the rotation of the rotor **40**, electromagnetic induction further occurs between the directions of the magnetic fields and the wire **10** in the stator winding to generate an alternating current.

Further, as shown in FIG. **10**, the first claw magnetic pole element **45** of the rotor **40** may have four, six or eight claw-shaped bodies **451**, while the second claw magnetic pole element **46** may also have four, six or eight claw-shaped bodies **461**, in which the number of claw-shaped bodies **451** of the first claw magnetic pole element **55** is the same as that of claw-shaped bodies **461** of the second claw magnetic pole element **46**. The first claw magnetic pole element **45** and the second claw magnetic pole element **46** are engaged with each other so that the claw-shaped bodies **451** of the first claw magnetic pole element **45** and the claw-shaped bodies **461** of the second claw magnetic pole element **46** are adjacent to each other while slightly spaced apart from each other. As discussed above, when a current is passed through a magnetic pole coil **44** of a rotor, the first claw magnetic pole element **45** may be magnetized into an N pole due to electromagnetic induction, and the second claw magnetic pole element **46** may be magnetized into an S pole due to electromagnetic induction. Therefore, magnetic lines of force may be generated between each pair of the adjacent claw-shaped body **451** of the first claw magnetic pole element **45** forming the N pole, and claw-shaped body **461** of the second claw magnetic pole element **46** forming the S pole so as to form a magnetic field. If the magnetic field coil is arranged to be wound in a direction opposite the foregoing magnetic pole coil, the first claw magnetic pole element **45** is magnetized into the S pole due to electromagnetic induction, and the second claw magnetic pole element **46** is magnetized into the N pole due to electromagnetic induction. Similarly, magnetic lines of force may also be generated between each pair of the adjacent claw-shaped body **451** of the first claw magnetic pole element **45** forming the S pole, and claw-shaped body **461** of the second claw magnetic pole element **46** forming the N pole so as to form a magnetic field.

As shown in FIG. **11**, in a preferred embodiment of the present invention, a permanent magnet **50** or a permanent magnet **50** with a cover **60** is disposed between each pair of the claw-shaped body **451** and its adjacent claw-shaped body **461**. As shown in FIGS. **11** and **12**, the permanent magnet **50** may be fixedly disposed between each pair of the claw-shaped body **451** and the claw-shaped body **461** which are adjacent to each other. An N polar end **51** of the permanent magnet **50** is in contact with the claw-shaped body **451** of the first claw pole element **45** that forms the N pole, and an S polar end **52** of the permanent magnet **50** is in contact with the claw-shaped body **461** of the second claw pole element **46** that forms the S pole. As such, when an electric current enters the magnetic-pole coil of the rotor and a magnetic field is formed between each pair of the claw-shaped body **451** and the claw-shaped body **461**, the permanent magnet **50** can block linear passing of the magnetic lines between the adjacent claw-shaped bodies **451** and **461**, and avoid magnetic leakage, so as to reinforce the magnetic field formed by the adjacent claw-shaped bodies **451** and **461** and further increase the generating capacity of the alternator.

If the first claw pole element **45** is magnetized into an S pole due to electromagnetic induction, and the second claw pole element **46** is magnetized into an N pole due to electromagnetic induction, the permanent magnet **50** is disposed in such a manner that its N polar end **51** is in contact with the claw-shaped body **461** of the second claw pole element **46** and its S polar end **52** is in contact with the claw-shaped body **451** of the first claw pole element **45**.

In short, when the permanent magnet **50** is fixed between each pair of the adjacent claw-shaped body **45** and the claw-shaped body **46**, which has generated polarities due to electromagnetic induction, a polar end of the permanent magnet **50** is in contact with the claw-shaped body having the same polarity and likewise for the other polar end.

Also, as shown in FIG. **12**, an outer surface **53** of the permanent magnet **50** fixed between adjacent the claw-shaped bodies **451** and **461** that face outward is covered with a cover **60** made of a non-magnetic material. Not only can the permanent magnet **50** be protected by the rigidity of the cover **60** but magnetic leakage can also be further avoided through the non-magnetic properties of the cover **60**. In one embodiment of the invention, the non-magnetic material is stainless steel.

The permanent magnet **50** or the permanent magnet **50** with a cover **60** may be fixed between two adjacent claw-shaped bodies **451** and **461** in an embedded manner. FIG. **13**, which is a cross sectional view taken along Line A-A in FIG. **11**, shows a manner of embedding the permanent magnet **50** with its cover **60** between the two adjacent claw-shaped bodies **451** and **461**. The two opposite sides of a claw-shaped body **451** of the first claw pole element **45** and a claw-shaped body **461** of the second claw pole element **46** adjacent thereto are respectively provided with a groove **453** and a groove **463** by means of turn-milling, and the permanent magnet **50** with its cover **60** can be embedded between the two adjacent claw-shaped bodies **451** and **461** and received by the two grooves **453** and **463**. The N polar end **51** of the permanent magnet **50** is received in the groove **453** of the N-pole claw-shaped body **451**, and the S polar end **52** thereof is received in the groove **463** of the S-pole claw-shaped body **461**. In addition, FIG. **14**, which is another sectional view taken along Line A-A in FIG. **11**, shows another manner of embedding the permanent magnet **50** with its cover **60** into between two adjacent claw-shaped bodies **451** and **461**. A concave portion **55** is formed between inner sides of the claw-shaped bodies **451** and **461** by means of turn-milling, and the permanent magnet **50** with its cover **60** may be received in the concave portion **55** so as to be embedded between the two adjacent claw-shaped bodies **451** and **461**. The N polar end **51** of the permanent magnet **50** abuts against the N-pole claw-shaped body **451**, and the S polar end **52** thereof abuts against the S-pole claw-shaped body **452**.

To enable the permanent magnet **50** or the permanent magnet **50** and its cover **60** to be further fixed between the adjacent claw-shaped bodies **451** and **461**, an adhesive can be applied between the permanent magnet **50** or the permanent magnet **50** with its cover **60** and the claw-shaped bodies **451** and **461**.

The rotor structure with the permanent magnet **50** disclosed above can effectively increase the output current. Tests of cold temperature output and hot temperature output under different revolutions are conducted on the same wound stator made by double abreast wires of 1.5 mm diameter embedded therein (as shown in FIGS. **5**A, **5**B and **6**) in combination with a rotor **40** with permanent magnet **50**, and in combination with a rotor without permanent magnet, respectively. The results are shown in the following Table 2:

TABLE 2

		Rev(rpm)									
AMP		1,600	1,800	2,000	2,500	3,000	4,000	5,000	6,000	7,000	8,000
Cold temp. output	With permanent magnet	135.0	154.0	171.0	193.0	205.0	214.0	217.0	219.0	221.0	222.0
	Without permanent magnet	90.0	115.0	134.0	165.0	182.0	197.0	204.0	208.0	211.0	213.0
Hot temp. output	With permanent magnet	106.0	125.0	139.0	159.0	170.0	178.0	182.0	184.0	185.0	185.0
	Without permanent magnet	75.0	97.0	115.0	143.0	158.0	171.0	176.0	178.0	180.0	181.0

According to the result of Table 2, the cold temperature output current and the hot temperature output current of the rotor having permanent magnet **50** embedded between the adjacent N-pole claw-shaped body and S-pole claw-shaped body are always greater than those produced by the rotor without permanent magnet embedded between the bodies under any revolution. Please refer to the cold temperature output graph of FIG. **15**A and the hot temperature output graph of FIG. **15**B. The graphs indicate that the rotor structure having permanent magnet embedded between the adjacent N-pole claw-shaped body and S-pole claw-shaped body of the poles achieve better power generation efficacy than that without the permanent magnet embedded therebetween.

The rotor according to a preferred embodiment of the present invention should not be construed as being limited to the above specific embodiments. For example, the permanent magnets may be fixed between two adjacent claw-shaped bodies in another manner, or the permanent magnets may be disposed between only a part of two adjacent claw-shaped bodies.

A vehicle alternator consisting of the wound stator having double abreast wires embedded therein in combination with the rotor as described above has a miniature structure and also has the characteristic of high power generation efficacy. Meanwhile, the invention simplifies manufacturing procedures, makes automation easier, and allows for lower manufacturing costs. The foregoing embodiments are illustrative of the technical concepts and characteristics of the present invention so as to enable a person skilled in the art to gain insight into the content disclosed herein and to implement the present invention accordingly. However, it is understood that the embodiments are not intended to restrict the scope of the present invention. Hence, all equivalent modifications and variations made to the disclosed embodiments without departing from the spirit and principle of the present invention should fall within the scope of the appended claims.

What is claimed is:

1. A wound stator of an alternator, comprising:

a stator; and

a group of wires comprising a plurality of abreast wires, wherein the group of wires are embedded in corresponding grooves of the stator sequentially and the abreast wires in the grooves are oriented in a radial direction of the stator,

wherein each of the abreast wires comprises:

a plurality of wave-shaped coils, each of the wave-shaped coils being formed of straight portions and curved portions that alternate with each other, wherein the cross section of the straight portions of each of said wires is generally in elliptical shape, and the straight portions of the group of wires are sequentially embedded in the corresponding grooves of the stator along a direction of the major length of the elliptical shape,

wherein the group of wires for a stator comprises two abreast wires and each of the two abreast wires comprises a first end and a second end, and

wherein the straight portions of the two abreast wires are, starting from the first end, sequentially embedded in a forward direction in the corresponding grooves of the stator so that each of the corresponding grooves of the stator has two layers of wires embedded in a radial direction of the stator, and are then sequentially embedded in the corresponding grooves of the stator in a reverse direction and jut out from one of the corresponding grooves with the second end so that each of the corresponding grooves has four layers of wires embedded in a radial direction of the stator.

2. The wound stator according to claim **1**, wherein the two abreast wires are respectively connected in series to the first

end of another two abreast wires, the other two abreast wires starting from the first end thereof sequentially embedded in a forward direction in the corresponding grooves of the stator and jut out from one of the corresponding grooves with the second end of the another two abreast wires so that each of the corresponding grooves has six layers of wires embedded in a radial direction of the stator.

3. The wound stator according to claim **1**, wherein the two abreast wires are respectively connected in series to the first end of another two abreast wires, the other two abreast wires, starting from the first end thereof, are sequentially embedded in a forward direction in the corresponding grooves of the stator and are then sequentially embedded in the corresponding grooves of the stator in a reverse direction and jut out from one of the corresponding grooves with the second end of the other two abreast wires so that each of the corresponding grooves has eight layers of wires disposed in a radial direction of the stator.

4. The wound stator according to claim **3** wherein the generally elliptical shape has two flat sides.

5. The wound stator according to claim **3**, wherein the stator comprises an annular body, the annular body has a plurality of separating posts protruding inwardly and radially from an inner circumference of the annular body, an end of each of the separating posts extending from its two sides to form a plurality of magnetic shoes, and the grooves in the radial direction are defined between the separating posts, each of the grooves has an opening defined between adjacent magnetic shoes at the ends of adjacent separating posts, the width of each of the grooves is configured to receive only one wire, and the width of the openings of the grooves is slightly larger than the size of the straight portions of the wire, so the straight portions of the wires can be directly embedded in the grooves from the openings.

6. The wound stator according to claim **3**, wherein an electrical insulating material is laid on the surface of each groove of the stator, and the electrical insulating material comprises a material selected from a group consisting of a pressed paper board, a plastic film, a polyester film, aramid paper, and epoxy resin.

7. The wound stator according to claim **3**, wherein the stator has 72 to 96 grooves.

8. The wound stator according to claim **3**, wherein the plurality of the wave-shaped coils of the wires has 6 to 8 curved portions in the same curving direction.

* * * * *